Vol. XIV. — No. 4. April 1932.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621. 138]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

(XIIth SESSION CAIRO 1933).

QUESTION IV:

Methods to be used to increase the mileage run by locomotives between two repairs including lifting.

REPORT No. 1

(America, Great Britain, Dominions and Colonies, China and Japan),

by Sir Henry FOWLER, K. B. E.,
Assistant to Vice-President (Research and Development),
London Midland and Scottish Railway, Derby.

Replies were received from the following administrations:

America, North and South.

Argentine Republic	Buenos Ayres Great Southern Railway. Buenos Ayres & Pacific Railway. Buenos Ayres Western Railway. Central Argentine Railway. Cordoba Central Railway.
Brazil	V. F. do Rio Grande do Sul.
United States of America	Baltimore & Ohio Railroad. Delaware & Hudson Company. Erie Railroad. New York Central Railroad. Norfolk & Western Railway. Pennsylvania Railroad Company. Reading Company. Richmond, Fredericksburg & Potomac Railroad. Wabash Railway.

British Empire.

Great Britain, Northern Ireland and Irish Free State.	Great Western Railway. London Midland & Scottish Railway. London & North Eastern Railway. Southern Railway. Great Northern Railway (Ireland). Great Southern Railways (Irish Free State).
Africa	Gold Coast Government Railways. Kenya & Uganda Railway. Nigerian Railway. South African Railways & Harbours. Sudan Government Railways & Steamers.
Australasia	New South Wales Government Railways. New Zealand Government Railways.
Canada	Canadian National Railways. Canadian Pacific Railway.
Ceylon, Burma & Malaya.	Ceylon Government Railway. Burma Railways. Federated Malay States Railways.
India	Bengal Nagpur Railway. Eastern Bengal Railway (State Railway of India). East Indian Railway (State Railway of India). Great Indian Peninsula Railway (State Railway of India). Madras & Southern Mahratta Railway. South Indian Railway.

Japan and Colonies.

	Japanese State Railways. Government General of Chosen. Railway Bureau.

The questionnaire on which this report is based is embodied in the summary of replies given below. It is divided into six sections, dealing with :

- I. Heavy repairs.
- II. Periodical examinations.
- III. Intermediate repairs.
- IV. Materials, Design, etc.
- V. Operation.
- VI. General.

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Although steam locomotives were not specifically mentioned in the questionnaire, several questions have reference to this class only, and with one exception, no replies have been received dealing with any other type.

It will be appreciated that the repairs referred to in Question IV are those which necessitate the locomotive being dealt with in the main shops of the railway. This seems to have been generally understood from the replies received.

The first section deals with the reasons that render it necessary for a locomotive to receive such a class of repair, the organisation which decides when the engine shall be subjected to such a repair, and the arrangements made for its being called into the shops. The next two sections deal with the inspection and repair work carried out on the locomotive whilst absent from the main shops. It has been found that this work varies very considerably on the different administrations. This is probably due to local conditions, and the facilities available for such work. It is probable that the variations in this respect also account for the differences existing at present in the mileages between heavy repairs in certain cases.

In the fourth section, the question of material, design, etc., as affecting the maintenance of a locomotive is considered, whilst in the fifth section the operation of the locomotive in traffic is considered. Here again the local conditions have a very great influence on the results from the point under consideration.

In the last section the views of the various administrations were asked on the effect of recent alterations and improvements in increasing the mileage between heavy repairs. This naturally was a very important question, and although it has been dealt with fully in some cases, many administrations have replied in very brief and general terms.

For convenience of reference, each section has been split up into paragraphs which have been lettered, and it is proposed to deal with each of these paragraphs separately, and then to draw inferences from the replies as a whole.

I. — Heavy repairs.

a) *Upon what does the necessity for a heavy repair chiefly depend?*

Generally the replies of the various administrations show that the necessity for heavy repair depends chiefly upon the condition of the boiler. In the case of railways in the Argentine Republic, there are Government regulations which govern, on a mileage basis, the time when a locomotive shall be called in for repair. It is, however, inferred that the boiler is the chief factor, and the mileage may in certain cases be extended after inspection by a Government official. The Government regulation is stated to be:

a) with new boilers 94 000 miles;
b) with repaired boilers 62 500 miles.

In any case, if the mileage is not completed in three years, the locomotive must be called in at the completion of that period.

The New South Wales Government Railways also point out that, although the reason is chiefly the internal condition of the boiler, they are subject to departmental time and mileage regulations which must not be exceeded.

In Canada the Government regulation requires an external examination of the boiler to be made every five years, and the Canadian National Railways arrange that the heavy repair of the locomotive fits in with this. The Canadian Pacific Railway reports that although locomotives are called in owing to their general condition, it is chiefly due to tyre wear. It is interesting to note that the tyres of this company are specified to be of a very high tensile strength.

In very few cases indeed does the period depend upon mileage only.

I. — b) *What system have you for « calling in » a locomotive for heavy heavy repair?*

c) *Is this provisionally based upon time in service or mileage run since last heavy repairs?*

As will readily be understood, there are many different systems in use. It may be said that apart from countries where the regulations are governed by those imposed by Government, the condition of the locomotive is ascertained after a certain mileage has been run or a certain period has elapsed. These mileages or times vary with different classes of locomotives, and usually, taking all factors into account, the locomotive is « considered » for heavy repairs bearing these in mind.

I. — d) *How does this time or mileage vary between various classes of locomotives?*

The figures sent in are of very great interest, and it has been thought advisable to draw up Appendix I, giving in detail the figures received from the various administrations.

There is naturally a great variation in the mileage basis between locomotives on fast and slow services, and on the whole the fast passenger locomotives cover a distance between shoppings of at least twice that travelled by slow freight locomotives. It must be remembered that there is not only a relation of speed, but also of time in service to be considered, and that for a definite mileage, the time in steam of a freight engine is generally well over the time of a fast passenger service (except with express freight services, which are probably on the increase).

II. — Periodical examinations.

a) *What examinations are made whilst the locomotive is in service, to ascertain the state of the various parts ?*

b) *If you have schedules of periodical examinations, please forward copies.*

In practically all cases it is stated that there is a daily examination by the driver or a fitter. There are also examinations periodically by a special examiner, but the interval between these examinations naturally varies — in some cases very materially — between various parts and the various administrations. Usually the special examinations take place at periods which are multiples of a month. The Interstate Commerce Commission of the United States of America lay down in their regulations that certain parts must be examined monthly and three-monthly. The chief period is a month, and agrees with the period assigned for a thorough wash-out of the boiler.

Some railways, chiefly in Great Britain and its Colonies, conduct certain of their examinations on a mileage basis; the mileages are usually multiples of a thousand miles, so chosen that these examinations may synchronise as far as possible with those conducted on a time basis.

With the boiler, in many cases an examination each month by the shed staff is supplemented by an examination conducted by an inspector from headquarters every six months. This tends to give uniformity of treatment.

Appendix III gives a summary of the maximum and minimum times and mileages of the periodical examinations. On it are also the examinations asked for by the Interstate Commerce Commission of the United States of America.

II. — c) *What effect do you feel these examinations have on increasing the mileage between heavy repairs, i. e., by detecting flaws, worn parts, etc., and so preventing breakdown and failure ?*

There is a consensus of opinion that an organised system of periodical examination materially increases the mileage between heavy repairs. It prevents casualties and accidents, and in many cases allows material to be prepared in advance, so as to prevent delay whilst the locomotive is out of service for repairs. It is apparently looked upon as one of the most important factors in obtaining the desired mileage between repairs.

III. — Intermediate repairs.

a) *How do you arrange for these to be done, and just what work is done ?*

In practically all cases the two items mentioned in the full questionnaire, namely, the re-turning of the tyres and giving attention to axleboxes, are dealt with at some period between heavy repairs carried out in the main workshops. In some cases it is stated that tyres are if necessary replaced. To this work the name of « intermediate repairs » has been given. While the engine is stopped for this work, attention is naturally given to any other repairs, such as taking out a certain number of tubes to ascertain the state of the boiler, and if necessary cleaning it thoroughly, and attending to motion and brake work, etc.

III. — b) *Where is this work carried out — in the running shed or at a repair shop?*

Where this work is carried out depends upon the facilities provided in the sheds or depots. It may be taken that in the Argentine. in the United States of America, and in Japan, the work is done in the sheds, and the same is largely the case in India. In Great Britain and her Dominions and Colonies it is mainly carried out in repair shops. This is probably due to the fact that in Great Britain the distance to workshops is never very great, whilst in her Dominions and Colonies the engines are usually so scattered that it is unnecessary to provide equipment for this work at many points.

III. — c) *What mileages are the various classes of locomotives supposed to run before receiving these intermediate repairs?*

The figures here vary very considerably, in the same way as the mileages between heavy repairs. This is so for various classes of repair and also for the different administrations. Appendix II gives the mileages sent in by the various railways in reply to this question and the next, and also the total mileages between heavy repairs. (I *d.*)

III. — d) *What additional mileage does the intermediate repair ensure before a heavy repair is required?*

Although one railway states that the mileage is not increased by an intermediate repair, two others definitely state that an increase of 20 % and 25 % of the mileage which would otherwise be obtained between heavy repairs is the result of an intermediate repair. A fairly general statement is that an intermediate repair allows (and therefore one assumes, is necessary for) the desired mileage between heavy repairs to be obtained.

III. — e) *Is it the practice to co-ordinate intermediate repairs with the periodical examinations of parts such as pistons, valves, axles, etc.?*

In the majority of cases this is done, and apparently steps are taken to make the times coincide.

III. — f) *What is the time usually taken in making intermediate repairs which take an appreciable time, such as returning tyres, and other work carried out whilst this is being done?*

The answers to this question are set out in Appendix IV.

It will be noted that the periods and probably the work done vary very considerably. The extremely short time occupied in the United States of America is probably the result of regulations of the Interstate Commerce Commission, and also due to the fact that the work is carried out throughout the whole of the 24 hours each day. The apparent effect of the I.C.C. regulations will be dealt with later.

IV. — Material, Design, etc.

a) *What are your specifications for tyres and rails?*

In Appendices V and VI are given the various specifications received as far as tensile tests and analyses are concerned. It will be seen that those most usually employed are standard specifications of the British Standards Institution (late British Engineering Standards Association), and of the American Railway Association (A.R.A.) for tyres and rails, and the specification of Livesey, Son & Henderson for tyres. The Japanese State Railways and the Government of Chosen Railway Bureau have an interesting specification for rails.

It is difficult to make a comparison, owing to the same tests not always being made, but the matter will be dealt with later in the summary upon these notes.

IV. — b) *What do you feel should be the relation between tyre and rail to produce the best conditions in service ?*

c) *Have you studied this problem or carried out any experiments on it up to the present time ?*

Where an opinion is expressed with regard to the first of these questions, it is that the tyre should be somewhat harder than the rail. In one or two cases, preference is expressed for sorbitically treated tyres. Other heat treated tyres which have been tried in some cases are stated not to justify their use. It does not seem that any experiments on any scale have been carried out, although the Great Western Railway, and the London Midland & Scottish Railway, of Great Britain, and certain other lines have the matter in hand.

IV. — d) *What wear is permitted on tyres before they are taken out of service ?*

The Interstate Commerce Commission of the United States of America have definite regulations for the wear allowed, which are somewhat complex.

The question of re-turning tyres as well as scrapping them when worn is of very great importance in determining the mileage before repair, and this question will also be dealt with later.

IV. — e) *Please supply a drawing showing the section of a new tyre.*

f) *Have you experimented to ascertain the profile of the tyre most suitable to give the greatest mileage before returning is required ?*

The profiles shown by the drawings submitted consist of two standard types and a large number of types used by individual railways. The two standard types are those of the American Railway Association of the United States of America (fig. 1) — used in some cases with slight modifications — and of the Association of Railway Locomotive Engineers of Great Britain (fig. 2). The former, with double-tapered tread, is used in North America, and the latter, with plain tapered tread, generally in Great Britain, where it has been adopted as a standard of the British Standards Institution (late British Engineering Standards Association). In the latter there are three thicknesses of flange, the radii on all of them being the same.

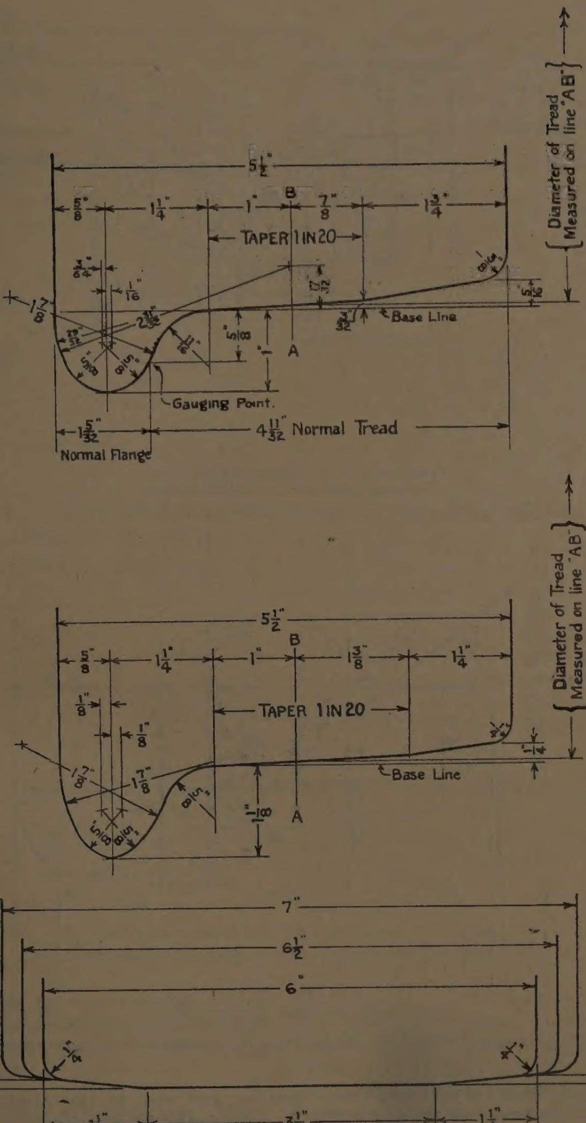
The other drawings submitted are very varied.

No considerable experiments seem recently to have been made on the effect of profile to give the greatest mileage before re-turning. This matter, however, is being considered by the London Midland & Scottish Railway of Great Britain, and the Burma Government Railway. The Emerson-Tatum profile (fig. 3) is used on certain vehicles of the Baltimore & Ohio Railroad. The Erie Railroad are trying tyres in which the double tapered tread usually adopted in the United States is eliminated, which they think will do away with slipping, and consequent wear, by giving greater adhesion. The question of varying tapers on the profile will be discussed later.

There is some variation as to depth of flange, which is generally between 1 inch and 1 1/8 inches, and the Great Western Railway have further increased theirs to 1 5/16 inches, with a view to obtaining a greater margin of safety. In the United States, on the other hand, there seems a tendency to use a flange 1 inch deep as against 1 1/8 inches generally employed a short time ago.

IV. — g) *What kind of gland packing do you use, especially for superheated locomotives ?*

A large number of types of gland

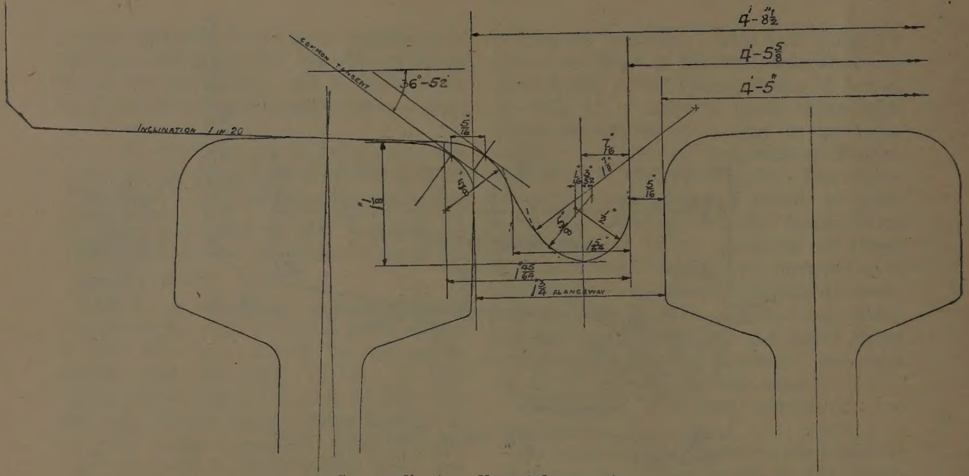


For steel tyred engine and tender truck wheels and flanged driving wheel tyres in switching service.

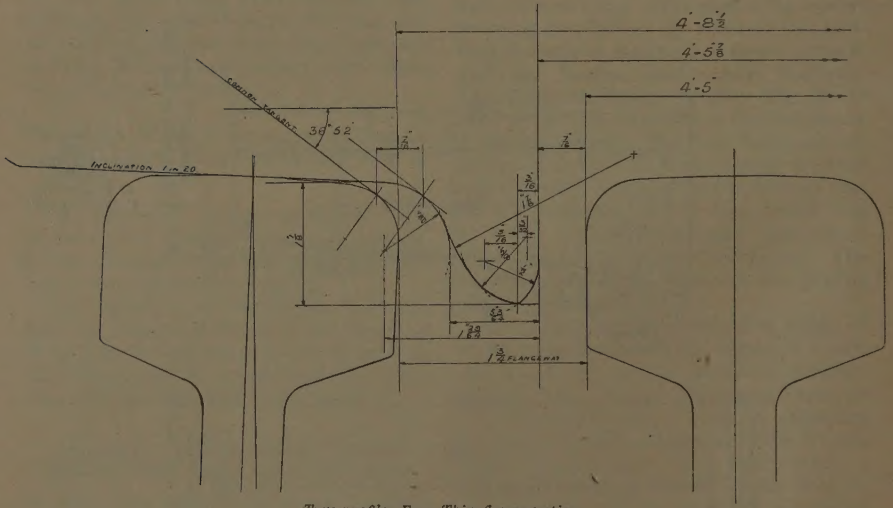
For flanged driving and trailing wheels of locomotives in road service.

Plain tyres.

Fig. 1. -- American Railway Association standard tyre profiles.
(From *The Locomotive Cyclopedia*, 1927, p. 644.)



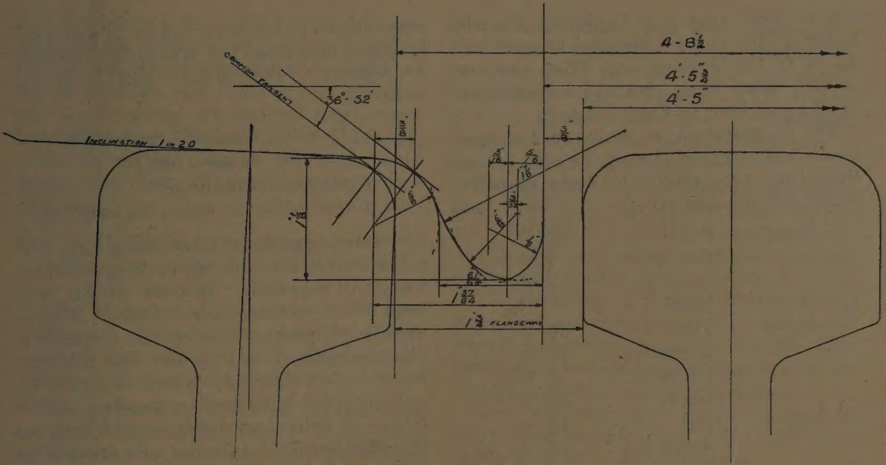
Tyre profiles A. — Normal flange section.



Tyre profiles E. — Thin flange section.

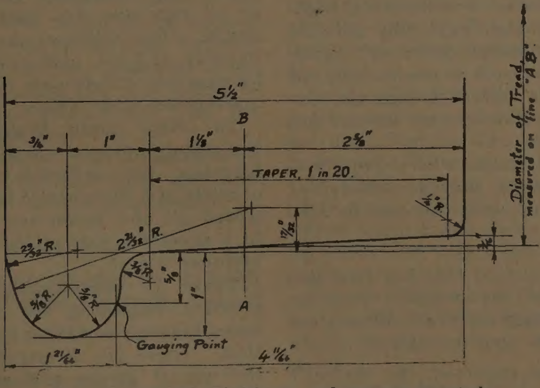
Fig. 2. — Tyre profiles, Association of Railway Locomotive Engineers (Great Britain).

packing are used, with very varied composition. Although many of these are of white metal in Great Britain and its Colonies, and also in the Argentine, there is a tendency to use a cast iron packing ring.



Tyre profiles G. — Thin flange section.

Fig. 2 (*continued*). — Tyre profiles, Association of Railway Locomotive Engineers Great Britain).



For steel tyred tender, freight car, and passenger car wheels.

Fig. 3. — Emerson-Tatum tyre profile, Baltimore and Ohio Railroad.

IV. — h) *What type of bearing metals do you use for axleboxes, and bearings for connecting rods? What is the composition?*

These vary very considerably. Many administrations use bronzes throughout in which the copper varies from about 89 % to 64 %, the lead from 28 % to 0 %, and the tin from 14 % to 4 %. A commonly used bronze contains copper 77 %, lead 15 %, tin 8 %. This is used by the Rio Grande do Sul, Delaware and Hudson, New York Central, New Zealand Government, Bengal Nagpur, and Government of Chosen Railways. It is interesting to note that the Canadian Pacific Railway, for special bearing bronze, use 0.5 % to 1.0 % of nickel. They and one or two other lines also use a small percentage of zinc in their bronzes.

The Association of Railway Locomotive Engineers of Great Britain, some little time ago, agreed to three standard white metals, namely :

No. 1. —	Tin.	85 %.
	Antimony . .	10 %
	Copper . . .	5 %.
	Lead.	—
No. 2. —	Tin.	60 %.
	Antimony . .	10 %
	Copper . . .	2 %.
	Lead.	28 %.
No. 3. —	Tin.	12 %.
	Antimony . .	13 %
	Copper . . .	—
	Lead.	75 %.

No. 1 is, of course, a well-known high-grade bearing metal, especially suitable for bearings in which there are variations of pressure, such as connecting rod big ends. Metals with such high tin content are only used on certain British and some other railways.

In the United States, where white metals are used at all, they are always of high lead content, as is the case in Australasia.

IV. — h) *Do you find that bad feed water influences the distance run between two heavy repairs ? What steps do you take to improve this ?*

As was to be expected, the majority of the replies indicate that bad water either influences the distance run between shoppings, or entails more work in the sheds to keep the locomotive in service. Some few administrations, as the Delaware & Hudson Railroad, Great Northern Railway of Ireland, Gold Coast Government Railways, New Zealand Government Railways, Burma Government Railway, Great Indian Peninsula Railway, and Federated Malay States Railways, report that their water is generally good, and does not affect the mileage or repairs. This matter will be dealt with later.

IV. — j) *What kind of oils and oiling systems do you use for :*

a) *Cylinder lubrication ?*

b) *Lubrication of axles, big ends, etc.?*

Details regarding lubricating oils for cylinders, axles and big ends are rather vague. Proprietary brands of oil are used to a considerable extent. Where details of composition of the respective oils are quoted, it is noted that oils for superheater steam cylinders are usually compounded with small amounts — up to 5 % — of animal or vegetable oil. Uncompounded mineral cylinder oils are in the main used for saturated steam cylinders, but the replies suggest that on some railways compounded oils of the superheater oil type are also used for saturated steam. One railway, the East Indian Railway (I.S.R.), uses castor oil for the lubrication of cylinders of engines with unbalanced slide valves.

The New South Wales Government Railways employ a special system of lubrication for cylinders. It essentially consists of a hydrostatic lubricator, from which oil and steam are led by a pipe to a special nozzle at the bottom of the cylinder barrel.

There is considerable diversity of practice regarding the lubrication of axles, big ends and other parts of the motion. There are frequent references to the use of grease and apparently this practice is extending. Pure mineral oils and oils compounded with fatty oils (rape oil and fish oil) in proportions up to 25 % are mentioned. Castor oil is also used on two Indian Railways.

IV. — k) *Is mechanical lubrication generally used, and if so, does it influence the mileage of the parts so lubricated?*

Of the 41 administrations, 30 report that they are using or have used mechanical lubrication to a greater or less extent. In the majority of cases it is stated that it has given satisfactory results as far as mileage and repairs are concerned. In six cases mechanical lubrication has either been taken off or no extension of its use is being made. Of these latter administrations, all but one are in hot climates.

IV. — 1) *Do you use any method of flange lubrication on your locomotives or on the rails of curves for the purpose of reducing the wear of the tyre flange? If so, is this general, or only in use on bad curves? What experiments have you made with it?*

The method of reducing flange wear by tyre flange lubrication is extensively used in North America, with the exception of the Pennsylvania Railroad, where rail lubrication is employed on bad curves, although the results so far are not definite. It is also employed on various other railways, and on the Ghat Railway of the South Indian Administration, where curves exceed 10°, it is stated to have more than doubled the time between « tyre profiling ».

In Japan various types of lubricators tried have not justified their use, and « tyre watering » is now employed.

V. — Operation.

a) *How are your locomotives manned, i. e., by single, double or triple crews?*

What is the general method of operation?

Where have you triple crews?

What experiments have you made with multiple crews?

The system of manning locomotives seems generally to depend on circumstances; with passenger services locomotives are more often allocated to particular crews than is the case with freight locomotives.

One or two replies are of special interest. The Pennsylvania Railroad, while saying that their locomotives are generally pooled, state that some passenger, freight and shunting engines are double-crewed, and a few passenger and shunting engines triple-crewed. This system is to be preferred if it can be arranged, as it maintains the personal interest of the crews in the locomotives.

The South African Railways generally pool their locomotives, but think this is not satisfactory from a maintenance standpoint, and when conditions permit, single and double crews are used.

The Delaware & Hudson Railroad find that multiple crews are the most economical for freight working, but the Erie Railroad have abandoned the use of assigned crews in favour of pooling.

The Japanese State Railways used to work with double crews, but now generally employ multiple crews.

In the United States of America in certain cases, the rule is one crew for each division passed through, which is also the case on the Canadian National Railways, although generally single crews are used.

On the Erie Railroad up to four crews per locomotive (100-120 miles per crew) are used, and on the Canadian Pacific in one case six crews are employed.

In Great Britain, single, double and triple crews are employed, here and elsewhere triple crews being used in shunting yards and with some passenger services.

On the Kenya and Uganda Railways the « caboose » system is employed, where the second crew sleep in the caboose.

On the Buenos Ayres & Pacific Railway during heavy traffic movement, goods trains are handled by five crews during a single journey of 430 miles.

The Great Indian Peninsula Railway is successfully carrying out experiments on a 562-mile run with triple crews, but they are having to change from oil to grease lubrication owing to hot boxes.

The long non-stop run of the London & North Eastern Railway of 393 miles with the crews changed on the road is well-known, as is the 301-mile run with a single crew on the London Midland & Scottish Railway.

V. — b) *What is the longest non-stop distance run in any service trip?*

The replies show three runs in Great Britain of over 200 miles, the London & North Eastern Railway's 393 miles (with two crews), the London Midland & Scottish Railway's 301 miles with a single crew, and the Great Western Railway report one of 225 3/4 miles. The latter railway also runs a freight train of 145 1/4 miles without a stop, and the London Midland & Scottish Railway a freight train of 191 miles without a stop.

A number of other administrations have runs well over 100 miles.

V. — c) *In what time can the driver take up the locomotive for a return working?*

The crews generally are allowed 8 hours' rest at a station away from home, and 12 hours when at home between shifts. The time allowed for preparing for a return journey may be up to 45 minutes.

V. — d) *Are special means adopted for cleaning the fire when bad coal is used?*

Practically all administrations state that they have no special trouble with bad coal, and rocking bars and drop grates are often used.

The Wabash Railway states that the worst fire can be cleaned in 12 minutes.

The New South Wales Government Railways have in addition ashpan flushing apparatus.

V. — e) *Have you considered any plans for improving the distance run by locomotives per day? If so, what are they, and what have been the results obtained?*

This question is such an important one, and the answers received are so varied and interesting, that a summary in each case has been made and is set out in Appendix VII.

V. — f) *What checks are made on excessive coal consumption per mile to prevent undue firebox and tube repair?*

In the majority of cases statistics are kept of the coal consumption of individual locomotives, and travelling inspectors are employed to watch consumption. One administration states that they find no relation between coal consumption and firebox repairs.

VI. — General.

Have any recent alterations or improvements in the design of engine or boiler, or has any change in operating practice materially helped in obtaining greater mileage between heavy repairs? If so, state what these have been.

The Argentine Railways point out, as previously noted, that their maximum mileage is limited by Government regulations. The Cordoba Central Railway states that welding the tubes into the firebox tube plate, and the welding in of a seamless plate in the corners of the firebox, materially helps them to reach this mileage.

The fuel used on the Rio Grande do Sul Railway has a calorific value of only 8 100 British thermal units per lb., with 30 % volatile matter and 30 % ash. The provision of large fireboxes, combustion chambers, and firebrick arches is found to be advantageous with this fuel.

The Baltimore & Ohio Railroad have found that the monthly inspection of staybolts represents one of their largest expenses, and they believe that the perfecting of their boiler with water-tube firebox, will practically eliminate this.

The Delaware & Hudson Railroad say they have benefitted by the application of one-piece cylinder frames and necessary castings.

The Erie Railroad refer amongst other items to the use of larger tanks and bunkers, mechanical stokers, firebox thermic syphons, and floating rod bushings; to the provision of water columns and improving the water supplied; and speeding up the turning of locomotives at terminals and so eliminating changes of firebox temperature.

The New York Central Railroad refer to large boilers, with superheaters and feed water heaters, the use of boosters, and the provision of large capacity tenders in order to reduce the number of coal and water stops.

Welding of various parts has practically eliminated trouble in the operation of boilers on the Norfolk & Western Railroad, whilst careful analysis of broken parts and consequent change of design has materially reduced failures on the road.

On the Pennsylvania Railroad there have been no recent alterations in design, although they are trying a water tube boiler. Longer runs have helped to give greater locomotive mileage, to reduce the number of locomotives required, and to permit the concentration of repairs at fewer points.

The Reading Railroad mention the points generally given above, and also mention exhaust steam injectors, higher manganese steel driving tyres (0.75 % — 0.95 % manganese), and tender boosters as being of help. .

The Great Western Railway say that alterations and improvements are continually being made in all directions.

On the London Midland & Scottish Railway, engines of modern design are found to give less trouble and longer mileage between repairs.

Boiler mileage is improved on the London & North Eastern Railway, providing they are of ample design, fed with suitable water, and properly washed out. The provision of three cylinders reduces the bearing pressure on machinery, whilst long non-stop runs give a higher daily mileage and a greater mileage between repairs.

The Southern Railway have found that locomotives of sufficient capacity have led to increased mileage and a reduction in failures.

The application of superheating on the Great Northern Railway of Ireland has led to greater mileage between repairs.

The substitution of « caboose » working for pooling shows a very beneficial result on the Kenya & Uganda Railway, with a considerable reduction in failures.

The South African Railways state that constant attention is given to points in design to increase mileage, but progress is gradual.

The improvements on the New South Wales Railways have already been dealt with in the replies to sections I — V.

In New Zealand there have been track conditions which have limited the weight of locomotives. Recently, however, these conditions have improved, and with the provision of more powerful engines, the distance between repairs has increased.

The Canadian National Railways give four points, namely, extended locomotive runs, heat-treated tyres, steel staybolts, and improved maintenance of boiler tubes and washing out of boiler.

The Canadian Pacific Railway point out that locomotive and boiler design is being continually improved, and on their line the average mileage between general repairs has increased in the past 8 years by 8 % for passenger and 13 % for freight locomotives.

The Burma Railways say that improvements in motion design have mainly contributed to improvement.

The East Indian Railway anticipate that hot bearings should be reduced by the extension of grease lubrication, which will allow of pooling and increased daily mileage, but probably not an increased mileage between shops.

The Great Indian Peninsula Railway cannot say that alterations of design have greatly helped in obtaining greater mileage between repairs.

The Madras & Southern Mahratta Railway feel that the greatest help to increased mileage between overhauls is given by prompt and good attention to repair in sheds.

The Japanese Railways have not altered design lately.

General summary.

The short summary of the replies to the separate questions gives a very good indication of the views of the various administrations which have replied to the questionnaire. One cannot but be impressed, however, with the varying conditions and results which pertain, even in the limited number of countries which this report covers. It will be noted generally that this is not so marked within the separate countries as between different countries, and it may be assumed that these differences are chiefly due to the conditions met with, and also possibly to some extent to customs and procedure which have grown up with the development of the railways and their lay-outs.

Speaking generally, there are two groups in which special conditions seem to regulate the mileages which are being dealt with. The first of these is the Argentine Railways, where the maximum mileage between heavy repairs is fixed by Government regulation, and the object therefore is to arrange that this maximum is reached. The other is the United States of America, where the regulations of the Interstate Commerce Commission specify a number of examinations which must be made periodically (see Appendix III). One of these is that « All boilers shall be thoroughly washed « out as often as the water conditions « require, but not less frequently than « once each month » (1). This means that every month the locomotive is taken out of service for certain definite work to be done upon it, and naturally the opportunity is taken advantage of to carry out other examinations and repairs. Usually the whole of the hours during which the locomotive is stopped is employed on this work, and facilities are arranged in the sheds or depots for handling the examinations and repairs in the most expeditious manner. The result of these, what may be called, short service intensive repairs, is shown in the comparatively high mileage obtained between heavy repairs.

Turning to the various sections into which the questionnaire has been divided, it may be said that the necessity for a *heavy repair* is mainly due to the work which has to be done on the boiler. Usually this takes a considerable length of time, even when, as is the case with some railways, a stock of repaired boilers of standard type is kept, so that the delay in this respect is cut down. Arrangements are almost universally made in the organisation for schemes by which, after a certain mileage or time, locomotives are reported upon, so that they may receive systematic repair at a time to be then defined. In most cases also, a mileage or time between heavy repairs is assigned for each class of locomotive.

Periodical examinations are also generally carried out at predetermined times or mileages, varying with the different parts of the locomotive. These examinations decidedly increase the mileage between heavy repairs by reducing failures which would necessitate the locomotive being out of service for a considerable time, as well as preventing disorganisation of traffic and the possibility of material damage.

The question of *intermediate repairs* is one which is dealt with in various ways. It is generally recognised that such repairs are necessary between the heavy repairs in the main shops, but the procedure and facilities provided vary considerably with the varying circumstances. Attention to tyre profiles and consequent re-turning seems to be one of the governing factors.

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(1) *Laws, rules and instructions for inspection and testing of steam locomotives and tenders and their appurtenance.* Washington, 1929, p. 55, para. 45.

In speaking of the effect of *material, design, etc.*, the general opinion seems to be that the tyre should be somewhat harder than the rail, as, all other things being equal, the tyre is subjected to greater wear. Very little attention has, however, been given to the relation between the composition and state of the material of these two essential parts of a railway, and it would also seem that the profile of the tyre has been developed largely empirically. In the United States of America and elsewhere, the tread of the tyre consists of two tapers, but at least one railway raises certain objections to this on the ground of reduced adhesion. The chief reason for the necessity for re-turning tyres seems to be wear of the flange, and, to retain the standard flange profile, metal on the tread of the tyre must be wasted in re-turning, and the life of the tyre diminished.

There seems to be no great move to adopt lubrication either of the tyre or of the rail on curves to prevent this flange wear, although certain railways use these methods — one administration with remarkably satisfactory results. The Japanese Government Railways, after experimenting with lubricants, are applying water to the flanges of their tyres. It should be said that one or two administrations state that they have in hand experimental work on the relation of tyre and rail.

The question of the supply of suitable water for the locomotive boiler is recognised as necessary to obtain greater mileage between repairs, and various methods are employed to achieve this.

The application of mechanical lubrication seems to be growing. It is interesting to note that in countries where the normal temperature is fairly high, there is a tendency to use grease for lubrication of the machinery of the locomotive, with the object of allowing longer runs per journey. No remarks have been made as to its efficiency as a lubricant.

In *operation* there is decidedly a move to increase the distance run by a locomotive per day, either by « pooling », or by arranging for several crews to operate the locomotive on its journey. This is probably one of the greatest factors in the universal increase of mileage between repairs, as undoubtedly the number of times a boiler is cooled down and heated up has a marked effect upon its maintenance.

In the replies as to what recent alterations have helped to increase the mileage between repairs, the majority of the administrations state that these have been shown in the detailed replies to the questions.

Final summary.

1. The chief reason for undertaking heavy repairs is the need of repair of the boiler; and a proper organisation for regulating heavy repairs is held to be very desirable.

2. A carefully worked-out system of periodical examination prevents failure and casualties and so eliminates irregular repairs.

3. It is practically always necessary for a locomotive to receive attention to tyres, axles, etc., between heavy repairs, and organisation should allow of these taking as short a time as possible.

4. The question of the relation between tyres and rail, and the profile of both of these, deserves closer investigation than has at present been given.

5. The quality of the water supplied to a locomotive boiler deserves the closest attention. This has a very material bearing on the mileage between heavy repairs.

6. Every method should be adopted to obtain as great a mileage per day as possible, as the increase of this helps greatly in the total mileage obtained.

APPEND

Table of time or mileage between heav

RAILWAY.	Express locomotives.	Passenger locomotives.	Heavy freight and articulated.
America, North and South.			
Argentine Republic.			
Buenos Ayres Great Southern	…	…	…
Buenos Ayres and Pacific			
Buenos Ayres Western			
Central Argentine			
Cordoba Central			
Brazil.			
Rio Grande do Sul	…	…	…
United States of America.			
Baltimore and Ohio	200 000	115 000—150 000	75 000—95 000
Delaware and Hudson	90 000	90 000—125 000	45 000
Erie	…	…	…
New York Central	90 000—110 000	…	49 000—65 000
Norfolk and Western	…	..	50 000
Pennsylvania	90 000	…	38 000
Reading	…	…	…
Richmond, Fredericksburg and Potomac.	…	…	…
Wabash	…	75 000—105 000	…
British Empire.			
Great Britain, Northern Ireland, and Irish Free State.			
Great Western	…	…	…
London Midland and Scottish	…	…	…
London and North Eastern	60 000—90 000	50 000—70 000	30 000—55 000
Southern	75 000—90 000	60 000—65 000	…
Great Northern (Ireland)	…	80 000	…
Great Southern (Irish Free State)	*22 months*	*30 months*	…

pairs for different classes of locomotive

Freight locomotives.	Local and tank locomotives.	Shunting.	All classes.	
			Miles.	*Months.*
...	...	...	94 000 (New boilers). 63 000 (Repaired boilers).	*36 months.* (Time limit).
...	...	...	31 000—112 000	*10—36*
90 000—110 000	...	100 000—165 000	75 000—200 000	...
60 000	...	75 000—90 000	45 000—125 000	...
...	...	...	70 000—130 000	...
55 000	...	58 000—61 000	49 000—110 000	...
100 000	...	...	50 000—100 000	...
...	...	...	38 000—90 000	...
...	...	...	30 000—60 000	...
...	...	...	...	...
60 000—75 000	...	30 000—60 000	30 000—105 000	...
...	...	...	...	...
...	...	...	...	...
40 000—70 000	...	...	30 000—90 000	...
55 000—60 000	55 000—75 000	50 000—60 000	50 000—90 000	...
60 000	...	...	60 000—80 000	...
30 months	*26 months*	*40 months*	...	*22—40*

APPENDIX I. (*Continued.*)

RAILWAY.	Express locomotives.	Passenger locomotives.	Heavy freight and articulated.
Africa.			
Gold Coast Government	...	80 000—150 000	...
Kenya and Uganda	...	...	...
Nigerian	...	...	...
South African	...	...	...
Sudan Government	...	62 000	...
Australasia.			
New South Wales Government	...	90 000—200 000	90 000—120 000
New Zealand Government	...	...	...
Canada.			
Canadian National	168 000 av.	83 000 av.	86 000 av.
Canadian Pacific	...	...	...
Ceylon, Burma, Malaya.			
Ceylon Government	...	...	...
Burma	...	125 000	50 000
Federated Malay States	...	...	...
India.			
Bengal Nagpur	80 000 *18 mths*	80 000 *18 mths*	80 000 *36 mths*
Eastern Bengal	100 000—120 000	90 000—120 000	...
East Indian	120 000	120 000	...
Great Indian Peninsula	...	100 000	...
Madras and Southern Mahratta	...	80 000—100 000	...
South Indian	...	...	...
Japan and Colonies.			
Japanese Government	...	...	...
Government of Chosen	...	62 000—93 000	...

APPENDIX I. (*Continued.*)

Freight locomotives.	Local and tank locomotives.	Shunting.	All classes.	
			Miles.	*Months.*
36—60 mths	...	*36—60 mths*	80 000—150 000	*36—60*
...	...	...	70 000	...
...	...	...	90 000—100 000	...
...	...	...	80 000—200 000	...
31 000	...	...	31 000—62 000	...
76 000—150 000	...	...	76 000—200 000	...
...	...	...	55 000—80 000	...
86 000 av.	...	...	68 000—205 000	...
...	...	...	...	*18*
...	...	...	80 000	*28*
120 000—150 000	100 000	150 000	50 000—150 000	...
...	...	...	120 000—150 000	...
80 000 *36 mths*	...	80 000 *36 mths*	80 000	*18—36*
75 000	50 000—75 000	50 000—75 000	50 000—120 000	...
75 000	...	40 000	40 000—120 000	...
65 000	50 000	...	50 000—100 000	...
60 000—80 000	50 000—60 000	50 000—60 000	50 000—100 000	...
...	...	...	...	*36 max.*
...	...	...	...	*36*
31 000—56 000	50 000—56 000	...	31 000—93 000	...

APPENDIX II.

Table of mileages for intermediate and heavy repairs.

RAILWAY.	Mileage before intermediate repair (I. R.).	Mileage to second intermediate repair (if any).	Mileage from intermediate to heavy repair.	Mileage between heavy repairs.
America, North and South.				
Argentine Republic.				
Buenos Ayres Great Southern	I. R. unnecessary.	...	...	63 000 (—)—94 000
Buenos Ayres and Pacific	25 000—62 000	...	...	63 000 (—)—94 000
Buenos Ayres Western	37 000—40 000	...	12 000—18 000	63 000 (—)—94 000
Central Argentine	I. R. unnecessary.	...	...	63 000 (—)—94 000
Cordoba Central	I. R. unnecessary.	...	...	63 000 (—)—94 000
Brazil.				
Rio Grande do Sul	19 000	...	13 000	31 000—112 000
United States of America.				
Baltimore and Ohio	50 000—105 000	...	25 000—95 000	75 000—200 000
Delaware and Hudson	20 000— 40 000	...	20 000—50 000	45 000—125 000
Erie	30 000— 65 000	...	30 000—65 000	65 000—130 000
New York Central	30 000 (freight locos.)	..	...	49 000—111 000
Norfolk and Western	25 000—50 000	...	25 000—50 000	50 000—100 000
Pennsylvania	19 000—45 000	...	19 000—45 000	38 000— 90 000 (+
Reading	...	...	20 000—40 000	30 000— 60 000
Richmond, Fredericksburg and Potomac.	45 000—65 000	...	45 000—65 000	...
Wabash	15 000—55 000	...	15 000—55 000	30 000—105 000
British Empire.				
Great Britain and Ireland.				
Great Western	...	...	...	...
London Midland and Scottish	45 000	...	Time basis only.	Time basis only.
London and North Eastern	I. R. unnecessary.	...	...	30 000—90 000
Southern	...	...	15 000	50 000—90 000
Great Northern (Ireland)	30 000	...	30 000	60 000—80 000
Great Southern (Irish Free State)	40 000—50 000	...	30 000	Time basis only.

APPENDIX II. *(Continued.)*

RAILWAY.	Mileage before intermediate repair (I. R.).	Mileage to second intermediate repair (if any).	Mileage from intermediate to heavy repair.	Mileage between heavy repairs.
rica.				
Gold Coast Government	25 000—50 000	...	25 000—40 000	80 000 (—) —150 000
Kenya and Uganda	...	...	...	70 000
Nigerian	30 000	30 000	30 000	90 000—100 000
South African	...	...	...	80 000—200 000
Sudan Government	19 000—37 000	...	9 000—19 000	31 000— 62 000
ustralasia.				
New South Wales Government	52 000 av.	...	...	(76 000 (—)—200 000
New Zealand Government	40 000	...	30 000	55 000—80 000
anada.				
Canadian National	...	...	50 000—75 000	70 000—200 000
Canadian Pacific	I. R. unnecessary.	...	...	Time basis only.
eylon, Burma, Malaya.				
Ceylon Government	30 000—35 000	...	45 000	80 000 (—)
Burma	25 000—75 000	...	25 000—75 000	50 000—150 000
Federated Malay States	40 000—50 000	40 000—50 000	40 000—50 000	120 000—150 000
dia.				
Bengal Nagpur	Time basis only.	...	15 000—20 000	80 000
Eastern Bengal	45 000—65 000	...	30 000—55 000	50 000—120 000
East Indian	20 000—60 000	...	30 000	40 000—120 000
Great Indian Peninsula	...	...	...	50 000—100 000
Madras and Southern Mahratta	25 000—50 000	...	25 000—50 000	50 000—100 000
South Indian	...	...	50 000	Time basis only.
Japan and Colonies.				
Japanese Government	25 000—40 000	...	Time basis only.	Time basis only.
Government of Chosen	13 000—44 000	...	16 000—46 000	31 000—93 000

APPENDIX III

Schedules of periodical examinations

	Interstate Commerce Commission U. S. A.	Maximum time.	Minimum time.	Maximum mileage.	Minimum mileage.	An average of all schedules
	Months.	*Months.*				*Months.*
Boiler	1	6	1 *week*	...	...	1
Safety valves	3	12	1 month	12 000	12 000	3
Lead plugs changed	1	6	2 *weeks*	...	...	1
Gauge glasses	1	6	*Daily*	...	...	1
Superheater	...	6	1 month	6 000	6 000	1
Injectors	1	6	1 month	12 000	6 000	1
Vacuum or air brake	3	6	2 *weeks*	10 000	6 000	1
Wheels and tyres	...	6	1 month	12 000	2 000	1
Crank axles and webs	...	6	1 month	10 000	3 000	3
Main and side rods and big ends.	1	6	1 month	20 000 main. 10 000 side.	3 000	1
Motion	1	6	1 month	10 000	3 000	3
Slide valves	...	12	1 month	12 000	6 000	3
Piston valves	...	6	1 month	30 000	12 000	3
Pistons	...	12	1 month	30 000	6 000	3
Cylinders.	...	6	1 month	30 000	12 000	3
Lubricators	...	6	1 *week*	6 000	5 000	1
Bogies and ponies	1	Intermediate repair.	1 month	20 000	6 000	3
Spring gear	1	6	1 month	45 000	6 000	1
Engine and tender drawgear.	3	6	1 month	20 000	20 000	3
Tanks and bunker spaces.	1	12	1 month	20 000	3 000	1
Smokebox and blastpipe	...	6	2 *weeks*	30 000	6 000	1

Note. — The maximum and minimum figures above are taken from all administrations, and do not refer to one railway only, e. g., 6 months is the greatest time which elapses between boiler examinations on any of the railways.

APPENDIX IV.

Table shewing time taken to effect an intermediate repair.

RAILWAY.	Days.	Hours.	Notes.
America, North and South.			
Argentine Republic.			
Buenos Ayres Great Southern	...	...	
Buenos Ayres and Pacific	...	...	
Buenos Ayres Western	8	...	
Central Argentine	10	...	20 days if boiler is changed.
Cordoba Central	...	...	
Brazil.			
Rio Grande do Sul	5—15	...	
United States of America.			
Baltimore and Ohio	...	24	
Delaware and Hudson	...	48—72	
Erie	7—14	...	
New York Central	2—4	...	
Norfolk and Western	3—4	...	
Pennsylvania	...	120	
Reading	...	24	
Richmond, Fredericksburg and Potomac.	3—6	...	
Wabash	3—5	...	
British Empire.			
Great Britain and Ireland.			
Great Western	...	...	
London Midland and Scottish	6—10	...	Week days. Specifically mentioned.
London and North Eastern	6 and over	...	do.
Southern	12—30	...	do.
Great Northern (Ireland)	10—14	...	
Great Southern (Irish Free State)	12	...	do.

APPENDIX IV. *(Continued.)*

RAILWAY.	Days.	Hours.	Notes.
Africa.			
Gold Coast Government	7—10	...	
Kenya and Uganda	8—10	...	
Nigerian	32	...	Week days. Specifically mentioned.
South African	...	250—500	1 000 hours for articulated engines.
Sudan Government	6—10	...	
Australasia.			
New South Wales Government	20	...	
New Zealand Government	28	...	
Canada.			
Canadian National	14—20	...	Week days. Specifically mentioned.
Canadian Pacific	10—22	...	do.
Ceylon, Burma, Malaya.			
Ceylon Government	6—12	...	
Burma	23	...	Schedule.
Federated Malay States	...	24	
India.			
Bengal Nagpur	...	...	
Eastern Bengal	14—21	...	
East Indian	Up to 15	...	
Great Indian Peninsula	12—36	...	Week days. Specifically mentioned.
Madras and Southern Mahratta	30	...	
South Indian	12	...	do.
Japan and Colonies.			
Japanese Government	2—5	...	
Government of Chosen	...	[illegible]	

APPENDICES V*a*, V*b*, VI and VII.

APPENDIX

Rail specifications —

RAILWAY (OR SPECIFICATION).	Weight of rail, lb./yd.	Process of manufacture.
American Railw. Engineering Association* (A.R.E.A.) specification 1925.	70—84 85—100 101—120 121—140	Open hearth.
British Standards Institution (B.S.I. — late B.E.S.A.) No. 9 — 1928 (bull head railway rails) Note: No. 11 — 1926 (flat bottom railway rails) is similar, with the following exceptions:— Basic open hearth higher carbon: C 0.55—0.68 %, S 0.06 % max., P 0.05 % max.	60—100	Acid open hearth. Basic open hearth. Acid Bessemer.
America, North and South.		
Argentine Republic.		
Buenos Ayres Great Southern	...	Open hearth.
Buenos Ayres and Pacific	...	...
Buenos Ayres Western	...	...
Central Argentine	...	...
Cordoba Central	...	...
Brazil.		
Rio Grande do Sul	...	A. R. E. A. or
United States of America.		
Baltimore and Ohio	...	Similar to A. R. E. A.
Delaware and Hudson	130	A. R. E. A ...
Erie	...	Similar to A. R. E. A

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* The designation of the American Railway Association is given as A. R. A. or A. R. E. A. by various

Va.

hemical analyses. etc.

C.	Si.	Mn.	S(max.)	P(max.)	Remarks.
0.53—0.70	0.15 min.	0.60—0.90	...	0.04	
0.62—0.77	0.15 min.	0.60—0.90	...	0.04	
0.67—0.83	0.15 min.	0.50—0.90	...	0.04	
0.72—0.89	0.15 min.	0.50—0.90	...	0.04	
0.45—0.55	0.15 max.	0.90 max.	0.07	0.07	Ordinary carbon
0.50—0.60	0.10—0.30	0.80 max.	0.06	0.06	Higher »
0.45—0.60	0.15 max.	0.90 max.	0.06	0.05	Ordinary »
0.55—0.65	0.10—0.30	0.80 max.	0.05	0.04	Higher »
0.40—0.50	0.15 max.	0.70—1.00	0.07	0.075	Ordinary »
0.45—0.55	0.10—0.30	0.90 max.	0.06	0.07	Higher »
0.60 min.	0.06 max.	0.75 max.	0.04	0.04	High carbon Clarence « special » plough steel.
...	...	...	...	...	Not given.
...	...	...	...	...	Not given.
...	...	...	...	...	Not given.
...	...	...	...	...	Not given.
Prussian State Railways specifications.					
specification 1925.					
specification 1925.		...	...	...	
0.54—0.67	0.10—0.25	1.30—1.60	...	0.04	
specification 1925.					

administrations. The initials used in the replies have been copied into this report.

APPENDIX Va. (*Continued.*)

RAILWAY (OR SPECIFICATION).	Weight of rail lb./yd.	Process of manufacture.
New York Central	80 90 105—127 105—127	Basic open hearth. do. do. do.
Norfolk and Western	...	...
Pennsylvania (under revision — tentatively using).	131 and 152	Basic open hearth.
Reading	...	A. R. E. A.
Richmond, Fredericksburg and Potomac.	...	A. R. E. A.
Wabash	...	A. R. E. A.
British Empire.		
Great Britain.		
Great Western	B. S. I. (late B. E. S. A.) but with:	
London Midland and Scottish	B. S. I. (late B. E. S. A.) higher carbon.	
London and North Eastern	...	Acid open hearth. Basic open hearth. Acid Bessemer.
Southern		Before 1931, B. S. I. (late B. E. S. A.) Open hearth. Acid Bessemer.
Northern Ireland.		
Great Northern (Ireland)	...	...
Irish Free State.		
Great Southern	B. S. I. (late B. E. S. A.) 1922.	
Africa.		
Gold Coast Government	B. S. I. (late B. E. S. A.).	
Kenya and Uganda	B. S. I. (late B. E. S. A.) Rep. No. 11 — 1922,	
Nigerian	...	...
South African Railways and Harbours	80 lb. B. S. I. (late B. E. S. A.) F. B. rail used.	
Sudan Government Railways and Steamers	...	...
Australasia.		
New South Wales Government	60 and 70 80 90 100 and 110	Open hearth. do. do. do.
New Zealand Government	B. S. I. (late B. E. S. A.) Rep. No. 11 — 1926.	

Chemical analysis (%).					Remarks.
C.	Si.	Mn.	S(max.)	P(max.)	
0.55—0.68	0.10—0.25	0.70—1.00	...	0.04	Medium manganese.
0.60—0.73	0.10—0.25	0.70—1.00	...	0.04	
0.62—0.75	0.10—0.25	0.70—1.00	...	0.04	
0.54—0.67	0.10—0.25	1.20—1.50	...	0.04	
...	...	...	...	...	Not given.
0.70—0.85	0.15—0.30	0.70—1.00	...	0.04	
pecification 1925.					
pecification.					
pecification.					
0.45—0.55	...	0.90—1.10			
0.45—0.55	0.10—0.30	0.90—1.10	0.06	0.06	Otherwise similar to B.S.I. (late B.E.S.A.) spec. 1928.
0.50—0.60	0.10—0.30	0.90—1.10	0.06	0.06	
0.40—0.50	0.10—0.30	0.90—1.10	0.06	0.07	
ligher carbon — now modified to:					
0.50—0.60	...	0.80—1.10			
0.40—0.50	...	0.80—1.10			
...	...	...	...	...	Not given.
ut spec. not given for 50 lb. new section flat foot rail.					
...	...	...	...	...	Not given.
...	...	...	...	...	Not given.
0.50—0.63	0.10 min.	0.60—0.90	0.07	0.04	
0.55—0.68	0.10 min.	0.60—0.90	0.07	0.04	
0.60—0.73	0.10 min.	0.60—0.90	0.07	0.04	
0.62—0.75	0.10 min.	0.60—0.90	0.07	0.04	

APPENDIX V*a*. (*Continued.*)

RAILWAY (OR SPECIFICATION).	Weight of rail, lb./yd.	Process of manufacture.
Canada.		
Canadian National	100 or less	Basic open hearth.
Canadian Pacific	100	Basic open hearth.
	130	do.
Ceylon, Burma and Malay States.		
Ceylon Government	Based on B. S. I. (late B. E. S. A.) Acid open	
Burma	B. S. I. (late B. E. S. A.) Rep. No. 11 — 1926.	
Federated Malay States	...	...
India.		
Bengal Nagpur	50 and under.	Basic open hearth or Duplex process.
	60—90	do.
	Over 90—115	do.
Eastern Bengal	Indian Railway Board specification.	
East Indian	...	...
Great Indian Peninsula	B. S. I. (late B. E. S. A.) Rep. No. 9 — 1928	
Madras and Southern Mahratta	...	...
South Indian	Indian Railway Board specification.	
Japan and Manchuria.		
Japanese State	38.3, 47.3 and 64.1	Basic open hearth.
Government General of Chosen		Japanese standard

APPENDIX V*b*.

RAILWAY (OR SPECIFICATION).	Process of manufacture.
British Standards Institution (B. S. I. — late B. E. S. A.) No. 9 — 1928 and No. 11 — 1926.	Open hearth and Bessemer acid. Open hearth Bessemer acid
With the exception of railways using B. S. I. (late B. E. S. A.) specifications for	
Buenos Ayres Great Southern.	...
New South Wales Government	...
Japanese State	[Max. stress + [1.575 × max. stress in tons

Chemical analysis (%).					Remarks.
C.	Si.	Mn.	S(max.)	P(max.)	
0.62—0.77	0.10—0.20	0.60—0.90	0.055	0.04	
0.62—0.77	0.10—0.20	0.60—0.90	0.055	0.04	
0.68—0.83	0.20 max.	0.70—1.00	0.055	0.04	
arth higher carbon.					
...	...	...	...	...	Not given.
0.50—0.60	00.5 min.	0.60—0.90	0.05	0.06	Indian Railway Board spec. I. R. S. (T.) 12. Jan. 1929.
0.55—0.68	0.05 min.	0.65—0.90	0.05	0.05	
0.58—0.70	0.05 min.	0.65—0.85	0.05	0.05	
(See Bengal Nagpur Railway).					
...	...	...	...	...	Not given.
and Rep. No. 11 — 1926.					
...	...	...	...	...	Not given.
(See Bengal Nagpur Railway).					
0.45—0.60	0.20 max.	0.60—0.90	0.050	0.055	
ecification No. 90.					

ail specifications. — Tensile tests.

Tensile test.				Remarks.
Max. stress tons per sq. inch)	Elongation %.	Test piece.		
		Gauge length.	Diameter.	
42—50 > 50—53	10 min. 15-12 min.	either 2" or 3"	0.564" 0.798"	Ordinary carbon.
46—50 > 50—55	12 min. 10 min.	do.	do.	Higher carbon.
44—50 > 50—53	12 min. 10 min.	do.	do.	Higher carbon.
rails, the following are the only railways including a tensile test in their specifications:				
About 55	About 10	2"	0.798"	
Not specified.		2"	0.564"	
2.5 × elong. %) must be not less than 110 (metric units)].				
er sq. inch + (2.5 × elong. %) must be not less than 110 (English units)].				

APPENDI

Locomotive tyre specifications.

RAILWAYS (OR SPECIFICATION).	Class.	Analysis —		
		C.	Si.	Mn.
American Railway Association (A. R. A.) spec. Recommended practice 1920 (as given in A. R. A. proceedings, Sect. III, Mech. 1920).	A. B. C.	0.50—0.70 0.60—0.80 0.70—0.85	0.15—0.35 0.15—0.35 0.15—0.35	0.50—0.75 0.50—0.75 0.50—0.75
British Standards Institution. (B. S. I. — late B. E. S. A.). Rep. No. 24, spec. No. 4.	C. D. E.	...	...	1921 spec. : 1928 spec. :
Messrs. Livesey, Son & Henderson's, spec. No. 6 — 1920. Ref. D. 700.	...	...	...	...
America, North and South.				
Argentine Republic.				
Buenos Ayres Great Southern		Messrs. Livesey, Son, and Henderson		
Buenos Ayres and Pacific	...	...	...	...
Buenos Ayres Western		Messrs. Livesey, Son, and Henderson		
Central Argentine		»	» »	»
Cordoba Central		»	» »	»
Brazil.				
Rio Grande do Sul				A. R. A. spec.
United States of America.				
Baltimore and Ohio	A. B. C.	0.50—0.70 0.60—0.80 0.70—0.85	0.15—0.35 0.15—0.35 0.15—0.35	0.50—0.75 0.50—0.75 0.50—0.75
Delaware and Hudson	1. 2. 3. 4.	... ...	... ...	... ...
Erie	A. B. C.	0.60—0.70 0.70—0.80 0.75—0.85	0.15—0.35 0.15—0.35 0.15—0.35	0.50—0.75 0.50—0.75 0.50—0.75
New York Central				A. R. A. spec.

I.

hemical analyses and Tensile tests

		Tensile test.				Remarks.
S max.	P max.	Max. stress, tons per sq. inch.	Elong. % min.	Red. of area % min.	Test piece. (Gauge length × diameter).	
0.05	0.05	46.9 min.	12	16	2"×0.505"	
0.05	0.05	51.3 min.	10	14		
0.05	0.05	55.8 min.	8	12		
0.05	0.05	50—55	13—11	...	2"×0.564"	
0.04	0.04	56—62	10—8	...		
		63—69	10—8	...		
0.035	0.035	56—62	8	...	2"×0.798"	
pecification — See above.						
...	...	...	...	.	...	Not given.
pec. D. 700 — See above.						
» » » »						
» » » »						
See above.						
0.05	0.05	44.6—51.3	14	22	2"×0.505"	
0.05	0.05	51.3—58.0	12	20		
0.05	0.05	53.6—62.5	10	18		
...	...	49.1—53.6	18—14	...	4"	
...	...	53.6—58.0	14—11	...		
...	...	58.0—62.5	11—8	...		
...	...	62.5—67.0	8—5	...		
0.05	0.05	49.1 min.	12	16	2"×0.505"	
0.05	0.05	53.6 min.	10	14		
0.05	0.05	58.0 min.	8	12		
See above.						

APPENDIX VI. (*Continued.*)

RAILWAYS (OR SPECIFICATION).	Class.	Analysis — %.		
		C.	Si.	Mn.
Norfolk and Western		Similar to A. R. A.		
Pennsylvania		" "		
Reading	A. B. C.	0.50—0.70 0.55—0.65 0.70—0.85	0.15—0.35 0.15—0.35 0.15—0.35	0.75 max. 0.75—0.95 0.75 max.
Richmond, Fredericksburg and Potomac		Similar to A. R. A.		
Wabash		Similar to A. R. A.		
British Empire.				
Great Britain.				
Great Western		B. S. I. (late B. E. S. A.)		
London Midland and Scottish	C. D.	Similar to B. S. I. (late B. E.		
	B.	...	...	...
London and North Eastern		B. S. I. (late B. E. S.		
Southern		B. S. I. (late B. E. S.		
Northern Ireland.				
Great Northern (Ireland)		B. S. I. (late B. E.		
Irish Free State.				
Great Southern		B. S. I. (late B. E.		
Africa.				
Gold Coast Government		B. S. I. (late B. E. S.		
Kenya and Uganda		B. S. I. (late B. E.		
Nigerian		Class D steel, treated with		
South African Rlys. and Harbours		B. S. I. (late B. E. S.		
Sudan Government Rlys. and Steamers.	...	...	...	...
Australasia.				
New South Wales Government	C. D. E.	Acid open hearth Basic open hearth and electric		
New Zealand Government		B. S. I. (late B. E. S.		

		Tensile test.				Remarks.
S max.	P max.	Max. stress, tons per sq. inch.	Elong. % min.	Red. of area % min.	Test piece. Gauge length × diameter).	
pecification.						
"						
0.05 0.05 0.05	0.05 0.05 0.05	46.9 min. 51.3 " 55.8 "	12 10 8	16 14 12	A. S. T. M. for tyres.	
pecification.						
pecification.						
lasses not stated.						
S. A.), 1928.						
...	...	42—48	18—15	...	2"×0.564"	
.) 1928, classes C. and D.						
.) 1928, classes C. and D.						
. A.), class D.						
. A.), class D.						
A.), class D, untreated.						
. A.), 1928, class D.						
he Sandberg process.						
A.), 1928, class E.						
...	...	...	...	...	...	Not given.
0.05 0.04	0.05 0.04	49—55 56—62 63—69	14—11 10—8 10—8	... ...	2"×0.564"	
A.). Class s not stated.						

APPENDIX VI. (*Continued.*)

RAILWAYS (OR SPECIFICATION).	Class.	Analysis — %.		
		C.	Si.	Mn.
Canada.				
Canadian National	...	0.67—0.77	0.20—0.35	0.65—0.80
Canadian Pacific.	...	0.65 max. 0.75 max. 0.80 max. 0.55 max. Contains 3% nickel.	0.35 max. 0.35 max. 0.35 max. 0.35 max.	0.75 max. 0.75 max. 0.75 max. 0.80 max.
Ceylon, Burma and Malay States.				
Ceylon Government			B. S. I. (late B. E. S. A.).	
Burma			B. S. I. (late B. E. S. A.).	
Federated Malay States			B. S. I. (late B. E. S. A.).	
India.				
Bengal Nagpur			B. S. I. (late B. E. S. A.),	
Eastern Bengal			B. S. I. (late B. E. S. A.),	
East Indian			Similar to B. S. I. (late B.	
Great Indian Peninsula			Similar to B. S. I. (late B	
Madras and Southern Mahratta			B. S. I. (late B. E. S. A.),	
South Indian			Similar to B. S. I. (late B.	
Japan and Manchuria.				
Japanese State	...	...	...	...
Government General of Chosen			Acid. Basic.	

		Tensile test.				Remarks.
S max.	P max.	Max. stress, tons per sq. inch.	Elong. % min.	Red. of area % min.	Test piece. Gauge length × diameter).	
0.045	0.045	67.0 min.	10	20	2'' × 0.505''	Yield point 37.9 tons per per sq. inch min. Min. Brinell hardness at centre of section: 245.
0.04	0.04	46.9—53.6	18	25	2'' × 0.505''	Over 63'' outside dia.
0.04	0.04	55.8—78.1	18—10	25	2'' × 0.505''	Over 52'' to 63'' o. d.
0.04	0.04					52'' o. d. and under.
0.04	0.04					Nickel steel tyres.
1928. Classes not stated.						
Class D.						
Classes not stated.						
1928. Class D.						
921. Class D.						
E. S. A.), 1928. Class D.						Min. yield point 50 % of max. stress.
E. S. A.), 1928. Class D.						Min. yield point 50 % of max. stress.
1928. Classes not stated.						
E. S. A.), 1928. Class D.						
...	...	...	...	...	...	
0.05	0.055	50.8 min.	130 minus max. stress in kgr./mm²	...	...	Not given.
0.05	0.045					

APPENDIX VII.

APPENDIX TO QUESTION V-*e* — « *Have you considered any plans for increasing the distance run by locomotives per day? If so, what are they, and what have been the results obtained?* »

America, North and South.

Argentine Republic.

Buenos Ayres Great Southern Railway.

This matter is always under consideration when timetables and engine working diagrams are being prepared. In passenger service, oil-burning locomotives regularly run distances up to 450 miles without change of engine. A steam sand-gun is used for tube cleaning while running.

Buenos Ayres and Pacific Railway.

Through locomotive running has been adopted on the principal passenger and freight trains, the maximum distances run per locomotive being 430 miles on passenger service, and 300 miles on freight service. Engine diagrams are arranged to ensure a quick turn round at out-stations. Water conditions being very bad, auxiliary tanks of purified water are hauled by the locomotives. An additional oil reservoir is fitted to the hydrostatic lubricator, to avoid refilling en route, while grease lubrication is employed for bearings.

Buenos Ayres Western Railway.

This question is dealt with from time to time and is satisfactory (verbatim).

Central Argentine Railway.

For the past 10 years, locomotive runs have been carefully studied with a view to increasing the daily mileage. For example, in passenger service, in one case, the locomotive mileage has been increased from 158 to 434 miles per trip, and a link of 13 locomotives has been replaced by a link of 6. In freight service, in one case, the mileage has been increased from 156 to 457 miles per trip, and a link of 11 locomotives replaced by a link of 6.

Cordoba Central Railway.

Longer runs have been tried experimentally, and then adopted. These have proved very successful, and have enabled the shed staff to be reduced at intermediate stations where engines used to be changed. Nowadays the crews only are changed, the engines being pooled. This system may be described as a diagrammed crew service.

Brazil.

V.F. Rio Grande do Sul.

We are always studying means of increasing the distance run by locomotives per day. This has been done in certain cases, by ballasting the track with stone, which has given good results.

United States of America.

Baltimore & Ohio Railroad.

Passenger locomotives run up to 425 miles per trip, and freight locomotives up to 356 miles.

Delaware & Hudson Company.

Passenger locomotive crews are operated over more than one division, and the mileage of locomotives in fast freight service has been increased by prompt terminal attention. The results so obtained have been very good.

Erie Railroad.

The present arrangement was worked out comparatively recently, and is thought to be the limit consistent with good operation at this time (verbatim).

New York Central Railroad.

The length of locomotive runs has been increased to the extent that operating conditions will permit. Main line passenger locomotives now operate up to 657 miles per trip, and freight locomotives up to 800 miles.

Norfolk & Western Railway.

After considerable experiments, we are now operating passenger locomotives over four engine districts (approx. 450 miles), and freight locomotives over two engine districts (approx. 225 miles).

Pennsylvania Rairoad Company.

We have not only considered but have actually made effective many locomotive runs of increased distance. Passenger locomotives are run over three locomotive divisions with three crews, the crews being changed at the end of each division. Freight locomotives are run over more than one division by one crew, the distance run depending on economic considerations (*i. e.*, overtime rates), or the « Hours of service » law. As a result, the number of locomotives required to run the service has been reduced, and we have been enabled to close down a number of locomotive sheds.

Reading Company.

Experiments on fast freight trains between Philadelphia and Newberry Junction have shown that six locomotives can be eliminated on three runs, and that we are justified in increasing locomotive mileage wherever possible.

Richmond, Fredericksburg and Potomac Railroad.

Locomotives are only kept in steam as the traffic demands, and these locomotives are handled, repaired and despatched as promptly as possible. For 1929, our average daily mileages were :

Passenger, 224 miles, freight, 137 miles. The average of all Class I railroads in the United States for the same year was : Passenger 165 miles, freight, 91 miles.

Wabash Railway.

We are operating a number of passenger and freight locomotives over two districts, changing crews on the line. The crews of shunting engines are changed in the yards. Lubrication of locomotives is performed by special men, to avoid delay while the crews are being changed.

British Empire.

Great Britain, Northern Ireland and Irish Free State.

Great Western Railway.

Matter continually under review (verbatim).

London Midland & Scottish Railway.

Expert scrutiny of engine workings is made, in order to eliminate standing and marginal times. The question of locomotive classification, and design for specific work is under constant consideration.

London & North Eastern Railway.

The introduction of a corridor tender, by which crews can be changed during running, gives a daily mileage in passenger service of 393 miles, in one case. Freight engine mileage has been increasd by changing crews en route, and lodging the relieved crew away from home.

Southern Railway.

This subject is kept constantly under review (verbatim).

Great Northern Railway (Ireland).

Locomotives are crewed at different points which allow a maximum mileage per day (verbatim).

Great Southern Railways (Irish Free State).

Generally speaking, the distance run per day is limited by traffic requirements. On the main line, double trips (330 miles per day) have been made possible by special shed attention at the end of the outward trip.

Africa.

Gold Coast Government Railways.

Engines work double turns when train service permits, with two or more crews. Results show economies in fuel consumption and running repairs (verbatim).

Kenya & Uganda Railway.

The caboose system has recently been instituted on mail trains. Figures are as follows (average daily mileage taken over a period of a month): Before institution of caboose system, 145 miles; best month since institution of caboose system, 197 miles; a recent month, since institution of caboose system, 168 miles (due to tube failures); with experience, it is hoped to reach 220 miles in future.

Nigerian Railway.

Engine runs are being extended as circumstances permit. Runs of 120, 150 and 186 miles are in operation to-day, and results obtained justify further extensions (verbatim).

South African Railways & Harbours.

The methods so far adopted are longer locomotive runs where possible at a higher speed. Pooling of engines also results in increased mileage. Grease lubrication for the coupled wheel axleboxes is being extended to the majority of our engines, as less time is needed for attention, and delays due to hot boxes are reduced.

Sudan Government Railways & Steamers.

Rostered engine cycles increased mileage by 50 %. Through working with double crews where applicable, further 50 % (verbatim).

Australasia.

New South Wales Government Railways.

The factors which control the distance a locomotive can run per day are : 1. condition of fire; 2. tender coal capacity. There are now in service a large number of engines fitted with large tenders, while rocking and drop grates are provided in the firebox to enable fires to be cleaned, and the ashes discharged from the ashpan en route. As a result, passenger locomotives are regularly running distances up to 400 miles per day, and freight locomotives up to 266 miles per day.

New Zealand Government Railways.

A certain degree of economy has resulted from pooling locomotives, and meeting transport demands with the least possible number of locomotives. This, however, is only applied to the less important services, as more efficiency is obtained from the crews on more important trains if pooling is kept down to a minimum.

Canada.

Canadian National Railways.

The mileage has been increased to as much as 10 000 miles per month on extended runs (verbatim).

Canadian Pacific Railway.

Increased mileage has been obtained by running locomotives over more than one division, and providing for prompt despatching at division points. At present, through running of locomotives is confined to passenger service, and has resulted in the monhtly mileage being raised from 4 000—7 000 miles, to 9 000—15 000 miles.

Ceylon, Burma, and Malay States.

Ceylon Government Railway.

This matter is given considerable thought when engine working diagrams are prepared, and the best possible use is made of available stock (verbatim).

Burma Railways.

On goods trains, the engines used to be changed twice in 385 miles (166—108—111); nowadays they are changed once in the same distance (166—219). This has worked well, and has been extended to the mail train also.

Federated Malay States Railway.

The average mileage run per day per locomotive in service is 104 miles. In order to obtain the maximum possible mileage, engines are re-manned two or three times during the 24 hours, whenever possible.

India.

Bengal Nagpur Railway.

Double manning has been considered, and the design of rest vans is under scrutiny. No results so far have been obtained (verbatim).

Eastern Bengal Railway.

Systems of pooling and extended runs in use on this railway with satisfactory results (verbatim).

East Indian Railway.

General pooling has been tried, but it has not been successful mainly due to the increase in hot bearings (verbatim).

Great Indian Peninsula Railway.

A number of plans have been considered, but the main obstacle to a more extensive engine usage is the trouble experienced with hot axleboxes. There has been a slow improvement, however (1925, 100 miles per engine per day; 1930, 121 miles per engine per day). With grease lubrication, it is anticipated that this figure will be very much improved.

Madras & Southern Mahratta Railway.

This Railway has not been able to introduce extended runs to any extent, owing to restrictions of bridges and track over sections of line (verbatim).

South Indian Railway.

It is the intention to increase the engine miles per day by the adpotion of pooling, and extended engine runs, but no necessity is felt at present to resort to these measures (verbatim).

Japan and Manchuria.

Japanese State Railways.

We are studying the question (verbatim).

Government General of Chosen,
Railway Bureau.

1. As perfect as possible examination and repairs. 2. Occasionally during ordinary rest time, we use locomotives for other service (verbatim).

[625. 162 & 656. 254]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

12th SESSION (CAIRO, 1933).

QUESTION I:

The protection of level crossings in view of modern developments in road traffic.

REPORT No. 1

(America, Great Britain, Dominions and Colonies, China, Japan and Egypt),

by A. NEWLANDS, C. B. E., M. I. C. E., Mem., Am. R. E. A.,
Chief Engineer, London, Midland and Scottish Railway.

Introduction.

In the construction of railways it was, and still is to a lesser extent, the practice at times to carry the tracks across roadways on the level of these roadways. Roads crossed in this way are, generally speaking, of three types :

a) Public roads which are maintained at the expense of the community for their use ;

b) and *c*) Occupation and private roads which are the property of, and used by, persons to whom they belong or who have private right of user on them.

This report will have reference only to railway level crossings over public roads.

The question of the protection of railway level crossings over public roads has from time to time received considerable attention from Governments and public bodies whose duty it is to protect the interests of the travelling public.

It is proposed, in this report, to summarise the information derived from official publications and from replies to a questionnaire issued to Railway Companies affiliated to the International Railway Congress Association in the countries enumerated in the heading of this report.

The existence of a railway crossing over a public road must obviously create some restriction on freedom of movement along that road. In the early days of railways, this restriction was not of the same moment as it is to-day owing to the more leisurely manner in which the pedestrian and horse-drawn traffic of those days moved along the roads, as compared with the speeds at which modern motor vehicles traverse the same routes to-day. A check of five minutes at a level crossing on a horse-drawn vehicle moving at 10 m.p.h. only represented the time spent in travelling about 800 yards, whereas it might represent to-day, in the case of a motor driven vehicle, the time spent in travelling a distance of 4 or 5 miles.

Due to this change in the speed of

TABLE I

Showing number of public road crossings over the different types of lines on the railway systems reported on.

	Main lines.				Branch lines.			Unclass-ified.		Total.
	Single line.	Double line.	Three lines.	Four or more lines.	Single line.	Double line.	Three or more lines.			
1st class roads	3 217	1 778	181	211	2 865	259	23	1 832	...	10 366
2nd — —	7 277	2 708	271	285	5 736	300	31	4 170	...	20 778
Other — —	9 052	3 475	496	136	9 284	1 127	59	48 122	...	71 751
Class of road indeterminate	...	...	...	...	...	...	...	...	4 771	4 771
	19 546	7 961	948	632	17 885	1 686	113	54.124	4 771	107 666
% of total	18.17	7.38	0.88	0.59	16.66	1.57	0.01	50.30	4.44	...

TABLE II. — Level crossings over public

Description of roads.	Main lines.											
	Single line.			Double line.			Three lines.			Four or more lines.		
	1st class.	2nd class.	Others.	1st class.	2nd class.	Others.	1st class.	2nd class.	Others.	1st class.	2nd class.	Others.
America.	1 102	5 514	4 456	1 240	1 988	1 732	168	251	459	204	274	53
Great Britain and Northern Ireland	21	35	211	188	301	1 427	6	9	33	6	5	76
Irish Free State.	9	16	41	4	16	11	...	...	...	...	...	..
Australia	85	38	585	23	31	116	4	7	4	1	6	3
New Zealand	200	659	...	13	39	...	1	4	...	...	...	...
Canada	...	...	...	...	...	...	...	...	...	...	...	...
India and Ceylon	1 532	662	3 161	248	14	36	2	..	...	...	...	4
Crown Colonies	81	182	456	5	...	...	...	...	...	...	...	...
China	36	118	133	38	294	152	...	...	...	..	...	...
Japan	137	...	...	3	...	...	...	...	...	..	...	...
Egypt and Sudan	14	53	9	16	25	1	...	..	...	..	..	...
Totals . . .	3 217	7 277	9 052	1 778	2 708	3 475	181	271	496	211	285	136

traffic on roads, the incidence of accident at railway crossings has entirely changed for the reason that much more care is called for in approaching railway crossings at the high speeds of to-day than was necessary at the former low speeds.

The author proposes to deal with his remit under four main heads :

I. Statistics relative to accidents which have occurred in the various countries reported on.

II. The laws at present in force in these countries dealing with level crossings.

III. An analysis of the methods of protection in use at the present time in :

a) Great Britain and her Dominions, Colonies, etc. ;

b) The American Continent : United States of America and South American States ;

c) Other Countries : China, Japan and Egypt.

IV. General observations.

As a result of the issue of the questionnaire referred to, of which 87 copies were sent out, 55 answers have been received. In four cases recipients of the questionnaire were unable to give information in the form asked for as to number or description of level crossings, but a summation of the figures received shows that there are 107 666 public road level crossings in the above-mentioned countries, and these are classified and set forth in tables I and II in order of their importance both as regards importance of the railway and of the roadway.

roads. Distribution by countries.

Branch lines.									Unclassified as to number and description of lines crossed.			Class of road indeterminate.	Total.
Single line.			Double line.			Three or more lines.							
1st class.	2nd class.	Others.	1st class.	2nd class.	Others.	1st class.	2nd class.	Others.	1st class.	2nd class.	Others.		
1 299	3 347	4 413	87	80	174	13	17	13	859	932	12 472	67	41 214
182	351	1 513	155	177	884	7	13	45	...	...	...	171	5 816
88	279	246	8	32	2	2	...	...	...	...	...	...	754
197	66	1 553	7	3	23	1	1	1	...	...	...	...	2 755
415	1 242	...	...	...	...	...	...	...	...	...	...	...	2 573
...	...	...	...	...	...	...	...	...	403	762	28 085	...	29 250
598	154	1 189	...	1	...	...	...	...	...	...	...	2 066	9 667
47	259	336	...	...	...	...	...	...	...	...	...	102	1 468
9	38	34	2	7	44	...	...	...	...	...	...	1 965	2 870
30	...	...	...	...	...	...	...	...	570	2 476	7 565	...	10 781
...	...	...	...	...	...	...	...	...	...	...	...	400	518
2 865	5 736	9 284	259	300	1 127	23	31	59	1 832	4 170	48 122	4 771	107 666

These tables have been made as comprenhensive as possible. They show the number of railway lines crossed by 1st class, 2nd class and unclassified public roads, and these have been arranged under the separate headings of main line and branch line crossings. It will be seen from the tables that 50 % of the total crossings are unclassified both as regards the type of line and number of tracks crossed, although it has been found possible to classify them from the point of view of the importance of the road.

Classification of roads.

There appears to be no uniform method in operation whereby roads, and the railway crossings on them, in the various countries under review, are classified with regard to their importance. In some countries classification is based upon the importance of the road as affording communication between large centres of population. In others it is based on the density of traffic on the roads, while in some (notably in Japan), the level crossing classification is based upon the extent to which trains pass over it.

The Japanese method seems to commend itself as giving the most reliable indication as to the delay and risks that would be attendant on the use of a level crossing.

In Great Britain roads are designated 1st class when they connect important cities or towns, and 2nd class when they connect with 1st class roads. The classification does not have consideration to the extent to which a road is used by the public, nor to the width and constructional type of the road itself. Thus there are many 1st class roads, particularly in Scotland and in some parts of Northern England, which carry a small vehicular traffic, whilst in the Midlands and Southern England there are many 2nd class roads where the traffic is very dense.

In Canada and also in the United States of America the classification is usually based on road traffic density. Roads having an average traffic of 2 000 or more vehicles per day are designated 1st class, while those with more than 600 but less than 2 000 vehicles per day are designated 2nd class. This, although the general principle adopted, is subject to certain exceptions as each individual State in America has power to make its own regulations and laws with regard to its roads and their classification. In Japan a purely railway user classification is adopted : « 1st class » refers to the railway crossing and not to the road which crosses it. A « 1st class » crossing is held to be one which requires the services of a watchman for 24 hours a day in order to protect the railway traffic; a « 2nd class » crossing is one which needs watching during certain hours of heavy railway traffic only, while a « 3rd class » crossing has no railway protection of any kind.

The Government of India (Railway Department) classification has regard to the density of traffic on both road and rail, whilst in Australia and New Zealand there is no attempt at classification.

Reverting to the four heads under which this subject is to be treated, and taking these seriatim, we have :

Statistics relative to accidents.

a) Great Britain.

In Great Britain accidents at railway level crossings which involve loss of life or injury have by law to be reported to the Minister of Transport and the opinion expressed in a report presented by the Minister to Parliament, entitled : *Accidents which occurred on the Railways of Great Britain during the year 1930,* is that in spite of the intensive character of present-day road traffic, an examination of the statistics of accidents and casualties at public road level crossings justifies the conclusion that danger to the public from the existence of crossings is not on the increase.

For 1925-1929 inclusive the average annual casualties involving fatal accident or injury at public road level crossings with and without gates were 18 persons killed and 27 injured. This, for the average number of motor vehicles licensed annually for use on roads for these years represents 0.09 persons killed and 0.14 persons injured per 10 000 motor vehicles. In 1925 the total number of vehicles licensed was 1 537 340 as compared with 2 139 975, in 1929. The totals for the year 1930, when 2 230 104 vehicles were licensed, were 11 persons killed and 24 persons injured, or 0.05 persons killed and 0.10 persons injured per 10 000 motor vehicles licensed (excluding pedestrians the figures were 5 killed and 23 injured) thus shewing a definite decrease. Nor does it appear that the number of accidents, where casualties occur without fatalities or personal injuries resulting, is on the increase, the number in 1930 being 23, of which 19 were at crossings provided with gates and 4 at crossings without gates, whereas the corresponding figures for 1929 were 30 — 26 at crossings provided with gates and 4 at crossings without gates respectively. The question of the responsibility for such accidents has also been inquired into and it has been ascertained that in 1930 four of the accidents were attributable to breaches of the regulations on the part of railway servants, involving 11 persons being injured, while 19 accidents were due to want of care on the part of the public involving 11 persons being killed and 13 injured. Of the latter class, 7 have

TABLE III.

Year.	Killed.	Per 10 000 motor vehicles. Killed.	Injured.	Per 10 000 motor vehicles. Injured.	Number of licensed motor vehicles on roads.	Increase °/o over 1925.
Total for 1925 (pedestrians)	25 (12)	0.16	29 (8)	0.19	1 537 340	...
Total for 1926 (pedestrians)	24 (13)	0.14	31 (1)	0.185	1 677 652	9.2
Total for 1927 (pedestrians)	8 (6)	0.04	26 (15)	0.14	1 846 416	20.1
Total for 1928 (pedestrians)	18 (14)	0.09	12 (3)	0.06	1 998 384	30.0
Total for 1929 (pedestrians)	16 (15)	0.08	30 (8)	0.14	2 139 975	39.2
Totals	91	...	128	...	9 199 767	...
Average per year	18	0.098	26	0.14	1 839 953	19.7
Total for 1930 (pedestrians)	11 (6)	0.05	24 (1)	0.10	2 230 104	45.0

reference to pedestrians — involving 6 killed and 1 injured — and the remainder to road vehicle drivers — involving 5 killed and 12 injured. Table III below sets out the annual casualties at public road level crossings with and without gates for the five years 1925 to 1929 inclusive, together with the corresponding number of road motor vehicles and the ratio of killed and injured including pedestrians per 10 000 motor vehicles, and compares these figures with those for the year 1930, which is the latest year for which returns are available.

The totals for the same crossings for the year 1930 shew a definite decrease rather than an increase in the number of casualties.

If we include the accidents brought about by pedestrians at level crossings it appears that one person is killed per annum to every 500 crossings which exist, while one person is injured to every 230 such crossings. It is not the general practice, however, for Railway Companies to report to the Ministry of Transport accidents occurring at level crossings unless a collision with railway vehicles results; for 1929, 153 and for 1930, 127 such accidents were reported to the Ministry, but as the Railway Companies do not report the cases where public road vehicles run into closed gates at level crossings, these figures in all probability represent only about one quarter of the number of accidents which occurred. Such accidents may be taken as due to want of care on the part of the road user, and although these involve no personal injury they involve considerable material damage both to vehicles and to the property of the Railway Companies, and what is of more importance, each such occurrence is a potential source of accident which might involve serious injury or loss of life.

b) United States of America.

In the United States of America we find, from the statistics published by the Interstate Commerce Commission for 1929, that during the 13 years 1917 to 1929 inclusive, the number of motor vehicles increased more than five-fold, while the number of killed and injured in connection with motor vehicle accidents at level crossings about doubled itself. The number of killed and injured per 10 000 automobiles registered is given in 1917 as 2.17 ans 6.02 respectively, as against 0.64 and 1.96 in 1930. This shews a reduction of about 70 %. It should be noticed that in America although the rate of killed and injured

TABLE

Grade crossing accidents divided as

KIND OF PROTECTION.	Number of accidents.					
	1925	1926	1927	1928	1929	1930
Gates	210	227	192	179	180	119
Watchmen	568	603	606	643	642	471
Signals	777	884	922	1 089	1 191	1 075
Unprotected	3 897	4 148	3 876	3 841	3 899	3 131
Totals.	5 452	5 862	5 596	5 752	5 912	4 798

has been diminished, the incidence of accident is still greatly in excess of that in Great Britain.

TABLE IV.

Number of level crossings.

Kind of protection.	1925.	1926.	1927.
Gates	6 386	6 170	5 957
Watchmen . . .	7 935	7 765	7 554
Signals	12 964	13 992	15 213
Fixed signs . . .	202 348	202 620	203 817
Total. . .	229 633	230 547	232 541
Unprotected. . .	4 068	4 611	3 742
Grand total.	233 701	235 158	236 283
Increase.	...	1 457	1 125

Table IV shews for three years the comparative level crossing figures and the various methods of protection in operation, from which it will be seen that the number of crossings protected by gates and watchmen is decreasing while the number protected by fixed signals is increasing.

Table V shews grade crossing accidents divided as to type of protection and the deaths or injuries incurred divided as to type of vehicle.

Table VI shews the number of registered motor vehicles for the years 1925 to 1930 inclusive and the ratio of accidents to the total number of licensed motor vehicles. It is a matter of interest to note that the proportion per 10 000 motor vehicles both in killed and injured shews a steady decrease, dropping from 0.90 to 0.64 killed and 2.98 to 1.91 injured during these six years.

American opinion may urge that the diminution in the number of accidents is to be attributed to the increased number of fixed signs and signals now used as against the passing practice of having level crossing gates and watchmen, as the former method of protection is seen to be on the steady increase while the latter is decreasing, but one has to remember that the number of accidents is also decreasing steadily in Great Britain where practically no use is made of fixed signs and road signals, and gates and watchmen are the usual form of protection. Further reference will be made to this point under the third heading to be considered.

V

to the type of protection (U. S. A.).

Killed.						Injured.					
1925	1926	1927	1928	1929	1930	1925	1926	1927	1928	1929	1930
115	100	105	88	81	63	143	175	126	106	143	83
164	195	181	207	172	127	734	718	798	762	803	582
392	478	448	602	613	558	867	999	1 025	1 139	1 344	1 123
1 535	1 718	1 637	1 671	1 619	1 272	4 811	5 099	4 664	4 659	4 514	3 729
2 206	2 491	2 371	2 568	2 485	2 020	6 555	6 991	6 613	6 666	6 804	5 517

TABLE V. — *(continued)*. — **Deaths and injuries divided as**

	Killed.					
	1925	1926	1927	1928	1929	1930
Motor propelled .	1 797	2 080	1 992	2 175	2 108	1 712
Animal drawn . .	62	49	33	51	28	20
Pedestrian	299	300	299	299	307	257
Miscellaneous . .	48	62	47	43	42	31
Totals . .	2 206	2 491	2 371	2 568	2 485	2 020

TABLE VI. — **A** — **Number of motor vehicles registered on 31 December of each year in the U. S. A.**

	Percentage increase over 1925.
1925 — 19 954 357	—
1926 — 22 046 957	10.5
1927 — 23 127 000	15.9
1928 — 24 493 124	22.7
1929 — 26 501 443	32.8
1930 — 26 523 779	33.0

B. — Ratio of accidents to total number of licensed motor vehicles (**U. S. A.**):

		Killed.
1925	1 per 11 104 vehicles.	0.9 per 10 000 vehicles.
1926	1 " 10 599 "	0.94 " " "
1927	1 " 11 610 "	0.86 " " "
1928	1 " 11 261 "	0.89 " " "
1929	1 " 12 571 "	0.795 " " "
1930	1 " 15 492 "	0.645 " " "

		Injured.
1925	1 per 3 360 vehicles.	2.98 per 10 000 vehicles.
1926	1 " 3 460 "	2.89 " " "
1927	1 " 3 800 "	2.63 " " "
1928	1 " 3 922 "	2.55 " " "
1929	1 " 4 151 "	2.41 " " "
1930	1 " 5 074 "	1 97 " " "

c) Canada.

In Canada we find that much the same methods of protection are provided as in the United States of America. Gates, watchmen, bells and fixed signs and signals are all in general use throughout the Dominion. Under this system for the five years 1924-1928 inclusive the total number of accidents at level crossings was 1 476 resulting in 571 persons being killed and 1 946 being injured. The o type of vehicle (U. S. A.).

Injured.					
1925	1926	1927	1928	1929	1930
5 938	6 371	6 085	6 244	6 373	5 227
155	126	100	81	77	47
273	261	219	193	217	147
189	233	209	148	137	96
6 555	6 991	6 613	6 666	6 804	6 517

incidence of these accidents was as follows :

	Killed.	Injured.
a) Crossings protected by gates	24	68
b) Crossings protected by bells	78	242
c) Crossings protected by watchmen	8	51
d) Crossings unprotected .	461	1 585
Total. . .	571	1 946

The average per year for these five years was 114 persons killed and 389 injured. From this it appears that :

	Killed.	Injured.
324 accidents at protected crossings involved	110	361
1 152 accidents at unprotected crossings involved	461	1 585

but there is no comparable data shewing the proportion of unprotected to protected crossings for those 5 years. In the year 1929, however, there were 2 568 protected crossings and 28 771 unprotected crossings, which gives some indication of what the probable proportion was during the five preceeding years.

Table VIII shews the number of persons killed and injured at public road crossings for the years ending 31st December, 1924-1928 inclusive, and from this it will be seen that whereas the number of accidents occurring at level crossings protected by gates has decreased, those at unprotected crossings have increased nearly 50 %, but no information is available with regard to the increase or decrease at protected level crossings. The following extract from the statistics of the steam railways of Canada for the year ending 31st December, 1929, gives a summary of the accidents which occurred at highway crossings during that year, and it is of interest to note that in this case 27 % of the protected crossings were in urban areas and only 4 1/2 % in rural areas. The extract reads as follows :

> 128 persons were killed at highway crossings including 102 persons riding in motor vehicules, 6 persons riding in other vehicles, 19 pedestrians and one employee.

According to the statistics referred to there were 1 294 persons killed in all classes of motor vehicle accidents in Canada in 1929, including accidents involving motor vehicles and trains, consequently the 102 deaths caused by trains and motor vehicles colliding at level crossings constituted 8 % of the total. The number of motor vehicles registered in the year 1929 was 1 195 594 and the proportion of killed was therefore 10.8 persons per 10 000 motor vehicles.

TABLE VII. — **A.** — **Number of persons killed and injured at public highway**

GATES.		BELL.		WATCH
Killed.	Injured.	Killed.	Injured.	Killed.
11	15	10	47	...
1	14	9	50	1
7	20	21	65	1
4	13	16	45	...
1	6	22	35	6

B — **Number of highway crossing accidents and the nature of same, for each and**

	GATES.						BELL.					
	1924	1925	1926	1927	1928	Total.	1924	1925	1926	1927	1928	Total.
Automobile	2	7	10	3	3	25	30	32	39	34	31	166
Horse and rig	1	...	1	...	...	2	4	3	7	2	7	23
Pedestrians	21	4	9	12	5	51	4	...	5	4	3	16
	24	11	20	15	8	78	38	35	51	40	41	205

There were also 404 motorists injured at highway crossings, but there are no statistics at present available shewing the total number of persons injured in all motor vehicle accidents.

There were also 52 other persons injured at highway crossings, including 6 employees, 25 pedestrians and 21 persons riding in non-motor vehicles. Accidents at unprotected highway crossings were responsible for 75 % of the fatalities and 90 % of the injured, but 3 motorists and 3 pedestrians were killed at crossings protected by gates, and 16 motorists, 2 persons riding in non-motor vehicles and 4 pedestrians were killed at crossings protected by bells.

The number of persons injured at all protected crossings was 77, including 51 motorists, 8 persons in other vehicles, 15 pedestrians and 3 employees, 13 pedestrians being injured at crossings protected by gates.

On 31st December, 1929, there were 4 921 urban highway crossings, of which 1 338 were protected, and 26 418 rural highway crossings, of which 1 230 were protected. These include 224 highway crossings of Canadian Railways on United States territory.

Other countries. — Short surveys.

It is not possible to give such a comprehensive survey of accidents for the remainder of the countries embraced in this report, but some particulars of certain sections thereof will form sufficient guide to the whole.

rossings for the years ending 31 December 1924 — 1928 inclusive (Canada).

IEN.	UNPROTECTED.		TOTAL.	
Injured.	Killed.	Injured.	Killed.	Injured.
5	73	220	94	287
7	66	318	76	389
9	100	276	129	370
21	79	346	99	425
9	144	425	173	475

very year separate, for years ending 31 December 1924 — 1928 inclusive (Canada).

WATCHMEN.						UNPROTECTED.						TOTAL.					
1924	1925	1926	1927	1928	Total.	1924	1925	1926	1927	1928	Total.	1924	1925	1926	1927	1928	Total.
3	3	5	8	9	28	133	168	181	218	255	955	168	210	235	263	298	1 174
1	1	...	..	...	2	31	24	21	22	28	126	37	28	29	24	35	153
1	3	3	1	3	11	16	12	22	10	11	71	42	19	39	27	22	149
5	7	8	9	12	41	180	204	224	250	294	1 152	247	257	303	314	355	1 476

d) The Dominion of New Zealand.

New Zealand, with 2 573 level crossings, records the following accidents :

For the year ending 31st March, 1930, there were 99 motor accidents, involving 14 persons being killed and 31 injured, whilst horse and non-motor vehicles accounted for 12 accidents with 3 persons killed and 1 injured. Of pedestrians 4 were killed or injured. This shews 0.044 accidents per crossing.

For the year ending 31st March, 1931, there were 103 accidents in which motors were involved, resulting in 18 killed and 34 injured, while the accidents to horse and non-motor vehicles fell to 6 with only 1 person injured. Pedestrians killed were 4, with no injured. This shews 0.044 accidents per crossing.

e) Australia.

The figures for the New South Wales Government Railways provide a useful index as to the conditions existing in the Commonwealth. With a total of 3.675 level crossings there were 212 accidents during 1930, or 0.06 accidents per crossing.

f) India.

From India there is little information as to the total number of level crossings existing. Nearly 4 400 crossings are known to exist at which 46 accidents occurred in 1930-1931, or rather over 1 to every 100 level crossings.

It is alleged that two-fifths of these accidents were due to negligence on the part of railway companies' servants, and three-fifths to the negligence of the road users.

Summary.

The conclusion which may be arrived at, after consideration of these facts and figures, is that although the number of vehicles — and especially quick moving vehicles on the road — has increased to an enormous extent (in Great Britain, as an example, roads have had to be widened and new roads constructed in order to cope with the growth of road traffic), yet the number of accidents at level crossings instead of increasing at the same rate as the increase of vehicular traffic, is actually shewing a steady decrease. It may be inferred, therefore, that road users are of necessity becoming much more observant and more vigilant in using the roads. They are more on the look-out for signs and obstructions, and are consequently not taken unawares when they come upon an unexpected level crossing closed by a gate or otherwise protected. In this country, Highway Authorities and such organisations as the Automobile Association and the Royal Automobile Club are sanctioned by the Ministry of Transport (under Section 48 of the Road Traffic Act of 1930) to erect warning signs at difficult corners, cross roads, dangerous hills and such like for the instruction of the motorist. A further point is that the increasing use of the roads is developing a «road sense» in drivers, and has also led to the development of a code of hand and horn road signalling amongst drivers themselves which tends towards increased security on roads.

Laws and regulations at present in force.

The laws at present in force with regard to the construction and operation of railway level crossings may be briefly summarised as follows :

a) Great Britain.

In Great Britain the legal enactments for the protection of level crossings are laid down in various Acts of Parliament, the chief of which are the Railway Clauses Acts of 1845 and 1863, and for Light Railways the Act of 1896.

By the Act of 1845 the railway company has to provide and maintain gates across any public carriageway which is crossed on the level and employ persons to open and shut the gates and such gates have to be kept closed across such road on both sides of the railway, except during such time as road traffic may cross. The gates have to be of such dimensions that when closed across the railway they shall fence it in. If, however, it is thought desirable by the Minister of Transport in any particular case, that it is more conducive to public safety, he may order the railway company to keep the level crossing gates closed across the railway except during such time as railway traffic shall have occasion to cross the road.

In both cases a penalty of £2 may be inflicted every time a railway gatekeeper fails to return such gates to their original position after the passage of the road or rail traffic, as the case may be. Where a railway crosses a turnpike road adjoining a station, all trains, before passing across such level crossing, have to reduce speed to 4 m.p.h. and the Minister of Transport is empowered to make any rules and regulations with regard to such crossings from time to time as he shall deem necessary. (This requirement, as to speed, is seldom enforced in practice).

By the Act of 1863 it is not lawful to shunt trains across level crossings, or allow any train, engine or vehicle to stand on the same. Railway companies also have to provide and maintain a gatekeeper's house at public carriage-road crossings, and are subject to any regulations which the Minister of Transport may from time to time make with regard to such crossings and the speed at which trains may cross. Powers are also conferred by which the Minister can require a railway company to erect a bridge in lieu of a level crossing on grounds of safety and also require the company to carry out works best adapted for removing or diminishing the danger arising from the crossing.

The requirements of the Minister of Transport, dated 1928, have been compiled after consultation with the railway companies and although they have no legal force, are generally worked to by the railway companies. They provide that :

Crossing gates must be constructed to close alternately across the railway and across the road on each side of the crossing — they must be hung so as not to admit of being opened outwards towards the road, and must be provided with stops to keep them in position. Where the normal position of the gates is across the roadway, the gates must be worked either from a signal box or by a gatekeeper.

Where the normal position of the gates is across the railway, a gatekeeper is to be provided, unless, when required, the gates can be operated by a trainman.

Near populous places the gates have to be close barred or covered with wire netting. Red discs or targets for daylight, and red lamps, one on each side of a crossing, for night, have to be fixed on the gates, these to shew towards the road — also towards the railway if there is no fixed stop signal at the gates. Fixed signals of the distant signal type are only required when a sufficiently good view of the discs or lamps on the level crossing gates is unobtainable. The signal may be either a one position unworkable type, when it is only desired to give warning of the proximity of a level crossing, or a two position worked type. In this case the signal must be interlocked with the gates, and its position then informs the driver as to whether the gates are closed across the road or not. At important level crossings, stop as well as distant signals interlocked with the gates are required. At level crossings operated by gatekeepers a warning, by block indicator and/or bell or otherwise, of the approach of trains from either direction is usually provided.

At level crossings on light railways, when gates are not prescribed and cattle guards are used to prevent animals having access to the railway, speed restriction over and within a distance of 300 yards of the crossing is imposed, and a board has to be fixed at this distance on either side to indicate to the drivers the maximum speed permitted, together with a whistle notice ; and on the roadway at each of two points, 50 yards along the road in either direction, the railway company have to erect and maintain a notice board, which is generally fitted with reflectors of the cats-eye type cautioning the public to « Beware of the trains ».

The position thus is that in Great Britain the railway companies are responsible for the provision, maintenance and operation of gates at all public road level crossings.

The clearance between the gates and the lines of railway is usually from 5 to 6 feet, although cases exist where it is as low as 3 ft. 3 in. and as much as 45 feet where unimportant public roads cross railway lines.

b) Canada.

The Dominion of Canada Railway Act of 1919 provides that as regards level crossings :

a) The Railway Commissioners may make such order as they deem expedient for the protection, safety and convenience of the public;

b) Railways shall erect and maintain at each level crossing, sign boards bearing the

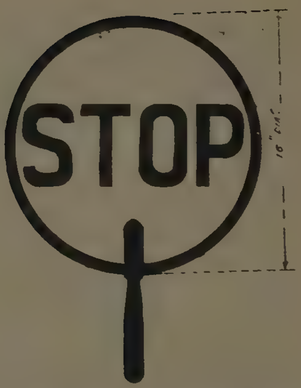


Fig. 1. — Metal flag for crossing watchmen, Canada.

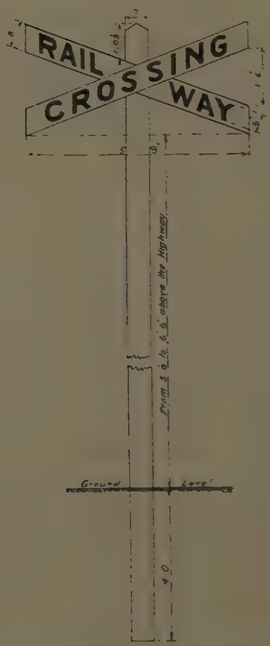


Fig. 2. — Highway crossing sign, Canadian Pacific Railway.

words « Railway Crossing » painted on each side in letters at least 6 inches in length;

c) When trains approach a highway level crossing, the engine whistle must be sounded at least 1/4 mile before reaching such crossing and the engine bell must be continuously rung from this time until the engine has crossed such highway;

d) Where a municipal bye-law of a city or town prohibits such whistling and bell ringing within its area — such bye-law shall, if approved by an Order of the Commissioners, relieve the Railway Company from the duty imposed in c) above.

The Railway Commissioners have issued the following General Orders in connection with highway crossing protection :

In August 1922. — That watchmen must display by day a metal disc marked « Stop », and by night a red light to warn highway traffic that a train is approaching. Where gates are provided a hooded red light to shew to the highway only must be displayed by night.

In September 1922. — The Order provides for the application of the above Order to Railways incorporated elsewhere than in Canada and owing controlling, operating or running trains or rolling stock in Canada.

In March 1929. — An Order provides for the procedure in making application to the Railway Commissioners for the construction or reconstruction of level crossings, the permissible width, grades and type of fencing to be employed. It also specifies as to signs and their location. These are shewn below:

A further order of this date gives specification for signals at highway crossings and instructions for their daily inspection and testing and the protection of crossings where a signal fails to operate.

In March 1930. — An Order provides that when a train or engine passes over any crossing protected by automatic signals or automatic gates and does not go beyond the end of the circuit, before making a reverse movement over the same crossing, a trainman must flag the crossing.

In April of the same year a further Order provides that all railway companies shall adopt and use a hand signal by day and a signal by clear (white light) lantern at night to protect the movements of vehicles over railways at highway crossings which trainmen are required to protect during the time trains are uncoupled at such crossings. *In May of the same year* an amendment was made to the Order of the previous March by the addition of the words « the ends of the circuit » at such crossings to be marked by a small finger-board with the words « End of block » at end of circuit. In the Province of Quebec all drivers of moter vehicles must stop before passing over a level crossing not protected by watchmen, gates or automatic signal device.

c) Australia and Zealand.

In New South Wales, statutory regulation only applies to the closing and fastening of unattended public road level crossings — the public have to shut and securely fasten any gate set up either side of a level crossing. For any breach of this bye-law there is a penalty not exceeding £10, and a notice to this effect is provided at such crossings. The staff are enjoined to shut any gates left open and to report promptly to the traffic superintendant of the district any default in this respect.

In South Australia, a bye-law prohibits persons from driving vehicles across the railway at unauthorised places or across authorised crossing places recklessly or in a manner likely to cause an accident with, or to, a train, or when warned not to do so by a Railway employee or by any mechanical, electrical or other warning device. Anyone infringing this bye-law is liable to a £10 penalty. In addition to the above there exist rules for the guidance of crossing keepers which define their duties and instruct them as to what they should do in emergency, etc.

In New Zealand the Government Railway Board have to metal and maintain the crossing over the railway and also the roadway for a distance of 33 feet from the centre of any line of rails crossed.

In 1926 it was enacted that the Board might cause such automatic signals to be erected in addition to the usual « stop » notice boards, as it considers necessary for the protection of persons using the crossing, but the Board are not liable in respect of any accident that may occur owing to the temporary failure of such signals. By the Amendment Act of 1928, every person driving a motor vehicle on any road must reduce speed when within 100 yards of a level crossing to a rate note exceeding 15 m.p.h. and must not accelerate until such crossing is passed. It is the motorists' duty to keep a sharp look for trains and he must not attempt to cross until the line is clear. Where « Compulsory stop » signs exist, every motor vehicle driver must stop at such sign for sufficient time to enable him to ascertain whether or not the line is clear.

Any person infringing these amended laws is liable to a fine of £10.

The « Compulsory stop » sign was provided for in the regulations made under the Motor Vehicles Act 1924, confirmed by Order in Council on 3rd April, 1929. This provides that any local authority may erect a traffic sign at any place in which in its opinion it is desirable that every driver of a motor vehicle should stop his vehicle.

d) India and Burma.

No laws, as such, exist in connection with level crossings. A document, however, is issued by the Government of India Railway Department giving a classification of, and standard specification for, level crossings. Apparently it is then left for the railway company to settle with the local governments and administrations concerned as to which category a level crossing belongs — special, A, B, C or D class. The method of protection adopted is gates, with lights on them at night. Where it is considered necessary, conventional signs will be erected by the road authorities on posts 100 yards from each gate and placed close to the edge of the road on the left of the vehicle approaching the crossing.

The Great Indian Peninsula Railway issue an order of their own that all level crossing gates, except those interlocked with signals, are normally to be kept closed and securely padlocked across the roadway, and are only to be opened by the gateman on duty for the passage of road traffic. He must then shew his danger signal (red flag by day and red light by night) to stop any approaching train until the crossing is clear.

Where chains are provided instead of gates, the chains are to be securely padlocked. At level crossing gates within station limits, when shunting operations have to be carried out which will foul the level crossing, thereby holding up road traffic, the gates must not remain closed for a longer period than 10 minutes if any road traffic is waiting. At level crossings provided with an electric bell or gong or telephone communication the gateman on duty, when advised of the approach of a train, must not open the gates for the passage of road traffic until the train has passed. Red lamps at busy level crossing gates are to be provided on the gate wings to shew a light in each direction along the line when the gates are closed against a train and along the road in each direction when the gates are closed against the road traffic. The gateman is responsible for seeing that the crossing as well as the channels for the railway wheel flanges are kept clear of all obstructions.

e) Ceylon.

Here gates have to be provided by, and at the cost of the railway company at all public road level crossings which are deemed by the Governor to be other than a minor crossing. These are kept closed across the railway except when in use. The Governor has power by proclamation to alter or vary the designation of any crossing and to provide for the gates being closed across the road instead of the railway in any case deemed expeditious. In the case of crossings designated as minor crossings, the gates are kept closed across the road and are fastened with a padlock.

f) Africa.

In Kenya and Uganda there exists a Railway Ordinance for the year 1927, where it is laid down that the Governor in Council may require the High Commissioner to provide either a level crossing or an over or underbridge and approaches where the railway crosses a road, and it also empowers the Governor in Council to at any time, in the case of a railway that has already been constructed, if it appears to him necessary for the public safety, require the High Commissioner to provide a bridge and approaches in lieu of a level crossing, and before the High Commissioner executes any works the Governor in Council shall take into consideration any representations made by the High Commissioner and the Road Authority ; the apportionment of the cost of construction and maintenance to be determined by agreement between the High Commissioner and the Road Authority, and, failing agreement, by the Governor in Council.

In Nigeria the railway company has to maintain a clear view at level crossings for both locomotive drivers and road users by clearing all land within the railway boundary from the point where the road crosses it to a point 500 feet in either direction from the crossing along the railway, and it has to maintain all necessary warning and whistle boards, lamps, etc. Where a new road is constructed on the level across an existing railway the Road Authority has to undertake work and maintenance under agreement with the railway.

There are no laws relating to level crossings in Rhodesia and Mashonaland.

g) United States of America.

In the United States of America there are no national enactments or regulations governing the protection of level crossings, the installation of protective devices and rules for operation at each location being covered by order of local Government State Commission or other governing body having jurisdiction over the crossings in that State.

The requirements of each State vary ; in some States, as in Georgia, Michigan, Ohio, Indiana, Illinois, Missouri and Iowa, crossing gates are not considered efficient or satisfactory for the present high speed road traffic and are being replaced with advanced warning signs and flashing signals.

In Georgia a crossing is classified as « safe » or « unsafe » according to its degree of visibility, and the requirements are that a crossing classified as « dangerous » shall be protected by a white sign with red letters 10 feet from the ground and 40 inches in size fixed on the right-hand side of the approach 100 feet from the crossings and lettered in 9-inch letters « Georgia Law — Stop — Unsafe. R. R. Crossing », and the motorist is required to bring his vehicle to a dead stop within 50 yards from the nearest rail before proceeding to cross the track. « Safe » crossings are required to be protected by exactly the same advanced sign, but the lettering is altered to « R. R. Crossing — Slow down to six miles — Ga. Law ».

In the States of New York, Massachusetts, Indiana, Illinois, Michigan and Pennsylvania, the railways are also required to furnish advance warning signs which are erected along the highway approximately 500 to 600 feet from the crossing.

In the State of Ohio these signs are only required at extra hazardous crossings. It should be noted here that all these signs have to be furnished by the railroad company but are erected by the highway maintenance authority.

The Rules and Regulations for the State of Virginia under Section 2145 (6) 1926, Section 5, order that :

> *a*) Except in cities and incorporated towns it shall be the duty of every person driving any vehicle on a public highway, on approaching a place where a railway crosses such public highway at grade, at which crossing no railway gates are maintained or no flagman is stationed and on duty at the time, to bring his vehicle to a speed not exceeding five miles per hour before passing over such crossing, at a distance of not less than fifty feet from the nearest rail of such railway tracks. Provided, that such person shall stop at such crossing where gates are maintained when such gates are closed down, or being lowered, and where a flagman is stationed and on duty at the time, whenever signalled to stop by such flagman; provided that this section shall not apply to any public railway crossing at grade on railway lines on which only purely local trains are operated.
>
> b) The provisions of this section shall not change or alter in any manner the existing laws as to the duty or liability of railway companies for damages to persons or property, and failure to comply with the provisions of this section on the part of the driver of the vehicle shall not be considered contributory negligence in an action against the railway company for damage to persons or property, whether the same be injury to the person or property of the driver or any other person. And it shall not be necessary to establish the fact that the driver complied with the provisions of this section in order to recover in any action for damages to persons or property against a railway company.

c) Except in cities and incorporated towns it shall be the duty of steam railway companies to erect and maintain, at every point where a public highway crosses such railway at grade, and on which line trains other than purely local trains are operated, a sign, visible for one hundred feet on each side of its tracks with the words « Slow down, five miles — Va. Law » in letters at least six inches in height painted in black upon a white background. Such signs shall be rectangular in shape, and of sufficient height to carry in two lines the words above required, and shall be of proportionate length.

d) Whenever, in the opinion of the State Corporation Commission, after giving notice and hearing as prescribed by law, the public interest requires that a gate be erected or maintained, or a flagman stationed at any highway crossing within five miles of the corporate limits of any incorporated city or town of this Commonwealth, it shall give the superintendent or manager of the railroad written notice that the same is required; and the company shall, within the time prescribed by the Commission, erect and maintain at such crossing the character of gate directed by the Commission, and keep a man in charge of the same during such hours as the Commission may designate, or keep a flagman at such crossing during such hours as it may require. And the said Commission may authorise the discontinuance of such gate or flagman whenever, in its judgment, the public interest no longer requires the same; and provided, however, that nothing herein contained shall affect any such gates or flagman heretofore established or maintained by agreement.

e) Any driver of any vehicle included in this act and any other person, firm or corporation violating the provisions of this act shall be fined not exceeding ten dollars for each offence. Provided, it shall be unlawful for any steam or electric railroad to erect, or continue in use, any sign worded *Main line — Danger — Stop*, except as provided in this act; and provided further, that no part of this act except the provisions of this section shall apply to electric railways.

In the State of Delaware, Chapter 213, Vo. 35 of the Laws of Delaware, provides as follows, with particular regard to the precautions to be taken by persons using highway grade crossings :

Whenever any person driving any vehicle approaches a highway or interurban electric or steam railroad grade crossing having a visible and protective signal giving warning of the approach of a railroad train or car, it shall be unlawful for the driver to fail to stop before crossing such grade crossing. Violation of this provision of the Motor Vehicle Law shall be considered a misdemeanour and punishable by the same fines and sentences as are now provided for by 249 Sec. 212 of the Revised Code of the State of Delaware.

The penalty for violating the above section is a fine of not less than ten dollars and not more than twenty five dollars and on failure to pay fine, imprisonment not exceeding ten days.

The requirement in Delaware with regard to crossing signs is found in Code Section 2035, Sec. 121, which reads :

Every railroad corporation formed under this Chapter shall cause signal boards, well supported by posts, or otherwise, at such heights as to be easily seen by travellers and not obstructing travel, containing on each side, in capital letters, at least five inches high, the following inscription: « Railroad crossing », to be placed and constantly maintained, at such public highways where it is crossed by the railroad at the same level: but such board need not be put up in cities or towns unless required by the authorities thereof. »

In the New Jersey Laws of 1924, it is provided that every railroad company shall cause a conspicuous sign with such inscription and of such standard and design as shall be approved by the Board of Public Utility Commissioners, to be maintained at each highway crossing at grade so as to be easily seen by travellers, but that such signs need not be maintained in any city, town, borough

or village unless required by the municipal authorities or by the Board of Public Utility Commissioners.

The minimum duties fixed by statute in New Jersey are that a bell or whistle be sounded as trains approach grade crossings and that signs be displayed as above stated. These minimum duties will be sufficient unless conditions of an extra hazardous nature exist on or about the crossing, in which event such additional duties will be imposed upon the railroads as the circumstances of the particular case require. It has been held that such extraordinary means of signalling the approach of trains must be taken only in the event of the crossing being so peculiarly dangerous that prudent persons could not use it unless these extraordinary means were taken. The statutes, however, allow the Public Utility Commissioners a wide latitude in fixing what safety precautions should be taken by railroads at grade crossings.

In the State of New York (Public Service Commission) the rules and regulations governing the installation and maintenance of automatic highway crossing signals are as follows :

1. *Aspect.* — When actuated by approaching trains, signals shall present to the observer upon the highway an appearance of a horizontally moving red light, the direction of which shall reverse alternately in accordance with a definite predetermined period.

2. *Support.* — Signals shall be supported on metal poles not less than four inches in diameter, securely fastened to an adequate concrete foundation or upon other equivalent form of support. Upon special approval by the Commission the lamps may be attached to the standard crossing sign required by section 53 of the Rairoad Law provided that sign is of the « X » or cross-buck type.

The lamps from which the light shall emanate shall be supported upon a horizontal bar attached to the aforesaid poles the lamps being mounted symmetrically with respect to the pole. The centre line joining the centre of lenses or roundels shall be not less than 6 feet or more than 9 feet above the surface of the highway. Where physical conditions permit the lower limit should be chosen. The distance between the centres of the lamps shall be 2 feet 6 inches.

Immediately above the horizontal bar supporting the lamps there shall be two crossed sign boards 4 feet in length, and 9 inches in width intersecting at their centres, bearing respectively the words « Railroad » and « Crossing ». The angle which these crossed boards shall make with each other shall be 90 degrees. The boards shall be fastened to the vertical pole at the point of intersection by a suitable device, the point of intersection of boards when attached to the pole to be not less than 2 feet 8 inches above the line, joining the centres of the lamps. Each board shall make an angle of 45 degrees with the vertical pole.

The letters on the boards shall be of Gothic type, 5 inches in height and the stroke on each letter shall be 1 inch. A border not less than one inch wide shall be provided on each board.

3. *Location.* — The signals may be installed either in the centre of the highway or to the right thereof as one approaches the railroard. One signal must be installed on each side of the railroad. In cases where the physical characteristics require that the signal shall be located on the left side, such location may be used after special permission therefore has been secured from the Commission.

Centre location. — If the signal is installed in the centre of the highway, the vertical pole supporting the signal shall be supported on a block of concrete not less than 2 feet high, and 5 feet wide at its widest point. The block shall be cast integral and shall be rounded at the end facing the traveller on the highway approaching the crossing, the radius of such rounding to be not less than 8 1/2 inches. The rear face may be plane or rounded and shall be not more than 15 feet from the nearest rail; the sides shall be formed in easy curves. The side faces above the surface of the highway shall have a vertical batter of not less than 2 inches per foot. The pole shall be located directly in the centre line of the highway and at the widest point of the base.

The roadway must be increased in width at the crossing so that there shall be a clear width outside the concrete block on each side of not less than 12 feet. The widening of the roadway shall be diminished gradually away from the railroad so that the normal width of the pavement shall be reached at a point not less than 75 feet from the signal. The widening shall be made with material similar to that used in the existing pavement, which shall be installed in a proper and workmanlike manner.

Each signal installed in the centre of the highway shall be equipped with a reflecting white prism located on the supporting pole as close as possible to the concrete base. This may consist of a single prism or a set of prisms. When installed it must be of sufficient size as to be clearly seen on a clear night when illuminated by the headlights of an automobile properly equipped in accordance with the Motor Vehicle Law, when such automobile is not less than 300 feet from the signal.

Side location. — When installed at other than the centre location, the supporting pole must be located to the right of the highway as one approaches the railroad not more than 15 feet from the outside rail of the tracks of the railroad, and not nearer than 6 feet nor more than 10 feet from the nearest edge of the pavement on the highway, unless local conditions, such as in city streets, require a different location. Should the physical characteristics require that the signal be located on the left side to insure adequate warning, such a location may be adopted, but in either event a specific location will be designated by the Commission upon application by the railroad corporation making the installation.

4. *Lights.* — The lights shall be actuated by electric circuits through suitable relays, and shall indicate the approach of a train for not less than 20 seconds before the train reaches the crossing, unless local conditions require a different interval in the case of a specific crossing, in which event the Commission will upon application by the railroad corporation fix the required interval.

Lamps shall be illuminated by electricity, and the number of alternations per minute shall be not less than 30, nor more than 45.

All lamps shall be hooded, so as to render them as visible as possible in the day time. Each lamp when operated at normal voltage shall have a range on a clear day, with a bright sun at or near the zenith, of not less than 300 feet when observed on a tangent.

The beam spread of each lamp shall be not less than 6 degrees each side of the axial beam under normal conditions.

Each lamp shall be equipped with red lenses or roundels which shall have an effective diameter of not less than 5 3/8 inches nor more than 8 3/8 inches. The transmission values for such lenses or roundels based on the American Railway Association Standard scale of values shall be not less than 160 nor more than 220 where plain cover glass with reflector is used; and not less than 220 nor more than 275 where reflectors are not used, or where ribbed spread light lenses are used in front of reflectors.

The bulb by which illumination is secured shall have a wattage rating which shall be best adapted to the type of lamp and lens used.

5. *Painting.* — The letters on the sign board shall be painted black on a white background. The border shall be painted black. The vertical pole from the base casting to the horizontal crossbar shall be striped diagonally black and white; the horizontal crossbar supporting the lamps and the lamps shall be painted black; above the crossbar the pole shall be painted black; the base casting shall be painted black. The concrete block shall be painted in checkerboard fashion, with black and white, each square to be not less than 9 inches.

In lieu of painted lettering, letters made of a reflecting material may be used. In this event the background of the board shall be black, and the border white.

State of Pennsylvania.—Executive ruling adopted 8 August, 1927.

The Department of Highways of the Commonwealth of Pennsylvania, The Public Service Commission, and such railroad companies as may become parties hereto, have agreed upon the establishment of a uniform type of warning signals, as follows :

1. — When automatic warning signals are authorised by the Public Service Commission at crossings of state highways with railroads, the railroad companies shall erect a signal on each side of the railroad which, actuated by approaching trains, shall present to the highway traveller the appearance of a horizontally moving red light the direction of which shall reverse alternately. The signals are to be erected and function in accordance with the recommendations of the signal division of the American Railway Association approved July, 1925. The railroad companies affected shall install and maintain the signals and the Department of Highways shall pay one-half of the cost of installation. If the installation is made under contract, competitive bids will be requested by the railroad companies; otherwise detailed estimates of the cost of installation will be prepared, and copies of such bids or estimates will be attached to the request for the Department of Highways' participation in the cost of installation and shall be approved as to acceptability by the Chief of the Bureau of Accidents of the Public Service Commission. Upon the completion of the installation a statement of the actual cost will be forwarded together with the completion report of the work.

2. — Where a full view of these signals is less than 500 feet on account of curvature or grade in the highway, an additional signal, consisting of a continuously yellow flashing light, shall be installed approaching the curve or grade, so as to give advance warning of the curve and the railroad; the Highway Department to erect and maintain such signals, and the railroad company affected to pay one-half of the cost of installation. Copies of bids or estimates of cost will be forwarded and approved as required where installation is made by the railroad companies, and upon completion of the work, certified statements of the actual cost will be forwarded to the railroad companies.

3. — Approaching dangerous curves, due to separation of grade of highway and railroad, where, in the opinion of the Chief of the Bureau of Accidents of the Commission, additional protection is necessary, similar continuously yellow flashing lights shall be installed, under the same conditions, namely, the Department to erect and maintain, and the railroad company affected to pay one-half of the cost of installation.

4. — The Department of Highways shall not permit the erection of any horizontal alternately flashing red lights on the State highways except for the purpose of indicating the approach of trains at such crossings.

5. — The use of the standard disc approach sign shall be continued and additional ones erected as necessary, and the Department of Highways shall recommend to the Township Supervisors the erection of these signs on township highways where they are not now in use, such discs to be paid for by the railroad company and erected and maintained by the local authorities.

The Department comments on the foregoing as follows :

The scheme would tend to the establishment of uniform protection devices at crossings now wholly unprotected and improvements over devices now in use at others, and subject to the following conditions and reservations is approved. This approval (1) shall not be construed to diminish or in any wise change or transfer the primary responsibility imposed on railroad companies by the Public Service Company Law and furnish and maintain service and facilities at and over grade crossings that shall be at all times safe to their patrons, their employees and to the public; nor to affect the duty of the railroads to change the protection measures when necessary or proper for the safety of any or all of said classes of persons; (2) is conditioned upon notice being given to the Chief of the Bureau of Accidents of this (Interstate) Commission of any proposed installation of lights under the arrangement and in sufficient time prior to the proposed installation to enable said Chief to make an investigation or inspection with respect to the crossing conditions and the sufficiency of the devices proposed to be installed.

It is interesting to note that in the States of New Jersey, Vermont and certain others, there are no requirements or laws whatsoever, the protection of each crossing being left to the discretion of the railway company involved, while in New Jersey and Delaware the highway traveller has laid upon himself the onus of using his eyes and ears in approaching level crossings so that he must protect himself from injuries and failure to take such precautions may be regarded as contributory negligence. The State of Delaware, goes even further and requires all vehicles to come to a standstill before attempting to pass over a level crossing.

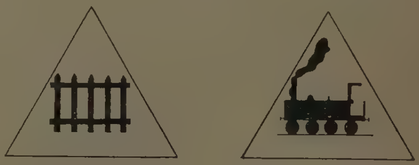
h) South America.

In the Argentine Republic under article 5 of Railway Law 2873, paragraph 8, it is provided that barriers *or* cattle guards shall be provided at all points where railways cross public roads or streets on the level. These barriers have to be closed for approaching trains and reopened as soon as after as possible.

The Pacific Railway Company states that the Government Railway Authorities can call upon them to provide alarm apparatus, the cost of which the railway company has to defray. In Brazil there are two decrees affecting level crossings — the first (No. 15673 dated 7th September 1922) has regard to the safety, policing and working of railways. It provides that, except in certain specifications, there are to be gates or barriers on both sides of the railway so as to block the street or public road during the passage of trains, and that cattle guards also be provided on either side of the crossing. The Government at its discretion may however dispense with the use of gates or crossing keepers at level crossings where either the road user or the railway traffic was light, but cattle guards in such cases are to be provided and in addition notice boards readily visible are to be fixed, at a convenient distance, to warn road users. Drivers are to whistle when approaching level crossings. Notice boards on either side of the crossing and at a distance of 500 metres are fixed with « Level Crossing — Whistle » on them. There does not appear to be any provision made whereby the drivers' attention is drawn to the presence of level crossings at night time.

By the second decree (No. 18 323 dated 27th July 1928) for the international transit of automobiles in Brazilian territory and for the signalling, safety and policing of motor roads warning signs as shewn in figure 3, drawings A and B above, are to be fixed along the road to draw attention to dangerous stretches, such signs to be fixed at the roadside not less than 150 metres and not more than 250 metres from the level crossings. The Government defrays the first expense and upkeep costs.

Brazil.



A. — Closed level crossing. B. — Open level crossing.

Fig. 3.

Columbian legislation prescribes keepers at every road level crossing, without any distinction being made as to the importance of the road. In one enactment it prescribes barriers of an automatic nature, if possible, and in another, chains. The intention is to alter the law and only to insist on keepers near inhabited centres.

In Uruguay, there are no Government or National regulations. The Central Railway have their own regulations. Special rules apply to meet the necessities of the case according to the intensity of the rail, and road traffic and the type of barriers to be provided. These rules are not specified.

It appears that on the Buenos Ayres and Western Railway Limited, practically speaking all barriers are manually operated, with the exception of four cases which are mechanically operated from signal cabins, and in these cases gates are used and close completely across the road and the railway respectively.

Other than the gates mentioned above, balanced poles without screens are used. In 1930, 19 accidents to vehicles took place at level crossings, 2/3rds of these occurred at unprotected crossings and of the 1/3rd at protected crossings, 2 were due to negligence on the part of railway employees and four to the road users.

j) Japan.

In Japan it is laid down that gates or other adequate measure shall be provided to protect busy level crossings. The regulations for railway construction also provide that guards are to be provided according to the density of the traffic both by road and rail. On Government railways where traffic is heavy during certain hours in a day, a watchman is stationed at the level crossings for that period except where automatic arresting devices or proper warning apparatus is provided.

k) China.

The regulations laid down for this country are simple and not onerous, providing merely for watchmen at busy crossings who are to control the traffic when a train passes. The watchmen have power to give signals to the engine drivers if required. In cases where two trains follow one another at an interval of 10 minutes, the watchman must stop the second, and for this purpose, he is provided with a detonator.

l) Egypt.

There are several Ministerial orders of a general character laid down for observance at level crossings of this country, but the Regulations laid down in the Railway Rule Book incorporate these and form the standards which are in operation.

These cover the lighting of lamps at gates, the duties of gate keepers, stationmasters and signalmen where the gates are interlocked.

m) Sudan, Iraq and Federated Malay States.

In the Sudan and Iraq no laws have been promulgated as to level crossings.

There is an enactment of 1912 in connection with level crossings in the Federated Malay States which provides that the Railway Administration shall cause gates to be erected and maintained and shall employ proper persons to open and shut such gates. Gates when closed have to fence the railway and are to be kept closed against the railway except when rail traffic passes. It is lawful for the Chief Secretary of Government to order that gates may be kept closed against the road instead of against the railway and he may impose conditions with regard to such order.

Summary of laws and regulations.

It can thus been seen that there is no lack of legislation with regard to protection at level crossings. In fact no country where any appreciable number of such crossings occur has failed to recognise the fact that their existence justifies very special enactments for the protection of the public using the railways and roads.

As has been shewn, however, the laws are not only very diverse in themselves, but also the stringency of the laws varies enormously in the different countries under consideration. In Japan, for instance, a general statement that adequate measures are to be taken by the railway companies, seems to cover the whole situation, while in the United States of America very great detail embodied in a vast number of laws has been promulgated.

Section III. — Methods of protection in use at the present time.

Great Britain.

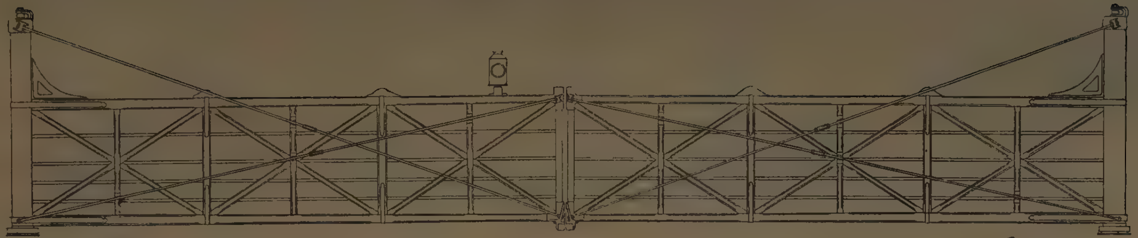
In Great Britain it has been the practice ever since railways were first constructed to provide gates at public road level crossings at the cost of the railway companies, and the railway companies are responsible for the maintenance and operation of these gates. These are usually of heavy wooden construction suitably braced with steel or iron tie rods, but in country districts and on narrow roads iron gates are sometimes used. In populous places it is usual to make the lower portion of the gate close-barred or to cover it with stiff wire netting or expanded metal. Of the 5 816 public road level crossings existing, the great majority are so protected, but at a few the protection is by chain ; where crossings are unprotected (mostly on light railways) warning boards are provided, visible by night and by day (generally effected by cats-eye reflectors being combined with the sign) while in addition whistle boards are fixed on each side of the crossing. Most of the cases of chain protection have been in existence a long time, having been provided prior to the passing of the legal enactements requiring gates to be provided.

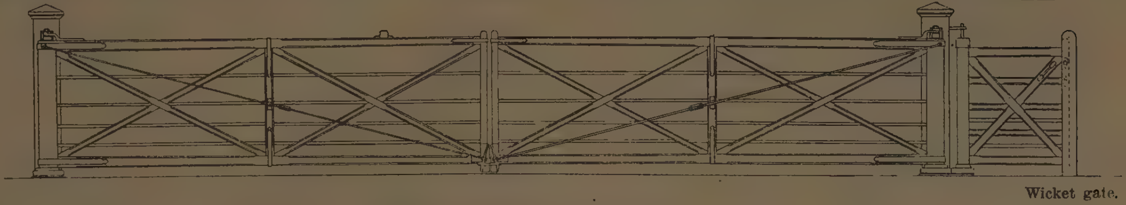
Crossing gates are operated either electrically, mechanically, or manually. About 49 % of the total number of crossings are manually operated, indicators and/or signals usually being provided, and operated by the gatekeepers of whom 46 % are male and 54 % female. As a rule gatekeepers have a cottage provided.

Only a few crossing gates are electrically operated, the remaining 51 % being practically all mechanically operated. The gates may be operated from an adjoining signal box and may be, and usually are, interlocked with the signals where these exist in the neighbourhood of the gates. If adjoining railway stations, in some cases the gates are operated by the station staff, and there are cases — a very few — of unimportant public road crossing gates which are opened and closed by the road users themselves. The normal position of the gates is across the public road, except on light railways where the gates may stand across the railway, being opened and closed by the train crew. In all these cases the railway traffic is small and the road user is considerable. With few exceptions the gates are fixed so that they may close completely across the road and/or railway alternately — by law they must do so in the latter case.

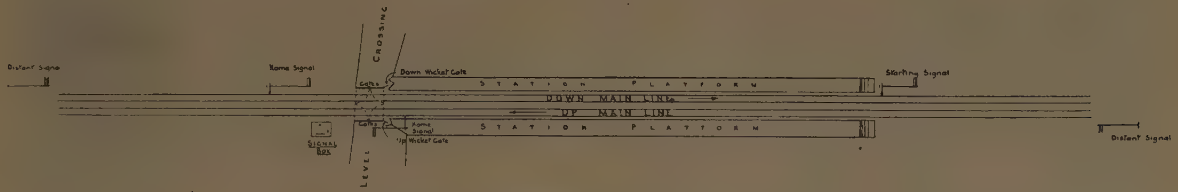
Warning signals on gates are generally provided by the railway companies. These signals take the form of a red target of circular or diamond shape for daylight use, and a red oil-lit lamp fixed to the gate on either side for use at night, and so placed that when the gates are placed across the road, a red indication is given that the road is blocked. The targets and lamps also shew towards the railway in the absence of a fixed stop signal at the gates. Such fixed signals are not necessary if a sufficiently good view of the discs or lamps is obtain-

Construction of gates 19 feet long or over.





Construction of gates under 19 feet long.



Typical level crossing.

Fig. 4. — Typical level crossing, Great Britain.
Gate protection in general use on London Midland & Scottish Railway.

Note. — Gates opened by hand wheel in signal box.

Signal box equipment:

Up wicket lever.	Gate stops lever.
Down wicket lever.	Gate lock lever.

Signal levers interlocked with gate stops and gate lock lever.

able by the engine drivers to enable them to stop short of the gates when closed across the railway. Rarely in this country are there any advanced warning signs, flashing lamps or any other device provided by and at the cost of the railway companies, to warn road users of the nearness of a level crossing, except in the case of level crossings on railways provided under the Light Railway Act, where warning boards have to be fixed on the road 50 or more yards on either side of the crossing.

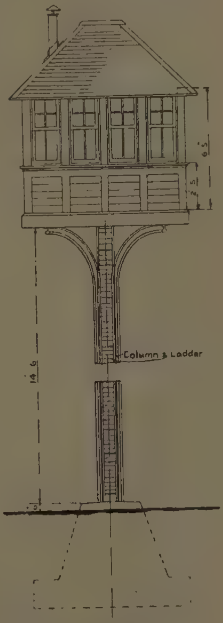
In certain cases warnings to motorists are provided by private enterprise or by independent bodies of their own volition to protect traffic but in these cases the warnings give no indication as to whether the crossing is blocked or not.

Canada.

The railways of the Dominion of Canada are under the control of the Board of Railway Commissioners and highway crossing signs are required by them to be placed at all level crossings, the installation and maintenance being at the cost of the railway company concerned. The sign takes the form of a 10-inch post standing about 6 feet above the road level with the cross buck sign « railway crossing », although in the province of Quebec the sign is in French and English. At crossings where there are one or two tracks only one sign is required painted on both sides, but where there are more than two tracks, a sign is required on each side of the crossing, the lettering being painted on one side of the cross buck only.

Where crossings have to be further protected, the Commissioners stipulate the type of protection to be provided and apportion out the division of cost as between railways, cities, towns, municipalities, provincial governments and the « railway grade crossing fund ».

This fund was created in 1919 by the Government of Canada towards helping to defray the costs of protection at crossings. The various methods adopted in Canada for the protection of level crossings are by means of mechanical or electrically installed barriers operated by gatemen in a tower adjacent to the crossings and by wig-wags or flashing lights automatically operated by approaching trains or by watchmen.



ELEVATION

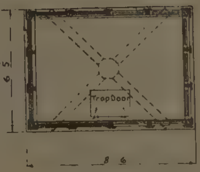


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Fig. 5. — Control tower, Canada.

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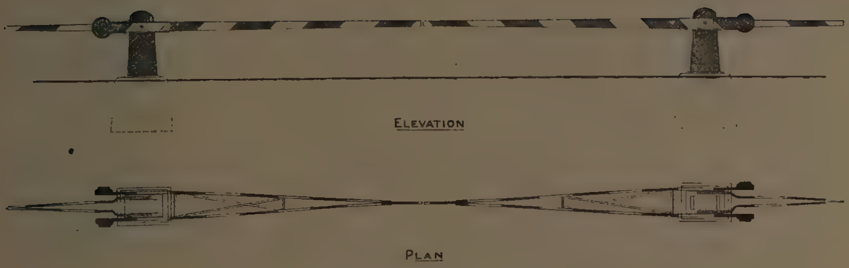


Fig. 6. — Canadian Pacific Railway standard highway crossing gates.

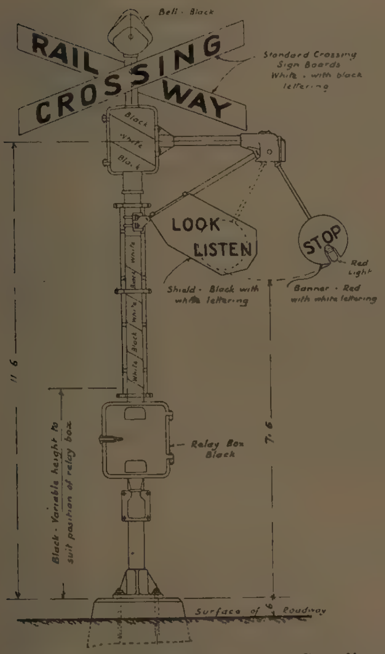

Bell - Black
RAIL
CROSSING
WAY
Standard Crossing Sign Boards White - with black lettering
Black
White
Black
LOOK
LISTEN
STOP
Red Light
Shield - Black with white lettering
Banner - Red with white lettering
White
Black
White
Black
White
11' 6"
7' 6"
Relay Box Black
Black - Variable height to suit position of relay box
Surface of Roadway
6"

Fig. 7. — Wig-wag signals on Canadian Pacific Railway.

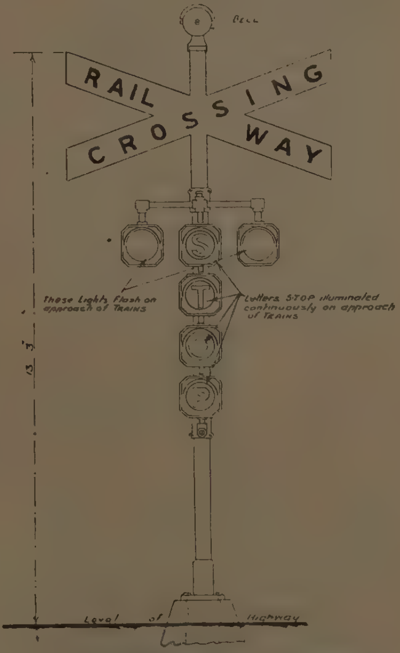

Bell
RAIL
CROSSING
WAY
S
T
These Lights Flash on approach of Trains
Letters STOP illuminated continuously on approach of Trains
13' 3"
Level of Highway

Fig. 8. — Flashing lights on Canadian National Railways (for side of highway).

The barriers illustrated herewith are of lattice design made of wood fitted into cast iron checks and counter-weighted. Provision is made for side walk attachments to protect pedestrians.

The barriers are equipped at night by

a lamp fitted with 2 red lenses which can be seen on the highway from either direction.

It is important to note that no provision is made to equip them with screens or fringes except in a few cases.

The barriers are controlled from a tower, a short description of which is as follows :

A roofed hut with glazed windows all round about 8 ft. 6 in. by 6 ft. 6 in. on plan is elevated about 14 ft. 6 in. on a built up steel column about 12 inches in diameter. This is approached by means of an iron ladder.

Where a crossing is protected by a watchman only, he is provided with a white disc for use by day and red lamps for use by night, as already described in the paragraph on the laws operating in Canada.

There are some cases where flashing lights of the United States pattern are in use, but the Railway Commissioners have adopted the wig-wag as the standard type of signal for Canada, it being specially ordered as follows :

« 1. That, until further notice, the specifications for signals at highway crossings are and shall be as follows :

Post. — The signal must be placed upon a post of suitable structural material. If the post is made of wood it must be of sound timber not less than 8 by 8 inches and 18 feet long, and shall be firmly set in the ground to a depth of four feet. If it is made of iron or steel it shall not be less than 4 inches in diameter, shall extend at least twelve feet above the ground, and shall be firmly bolted to a concrete or other foundation constructed below the frost line.

Bell. — A bell which shall emit a clear, loud volume of sound under all weather conditions must be used.

Wigwags. — Wigwags shall be of the three-aspect type, and when in operation must shew a clear bright light.

Operation. — The bell and the illuminated wigwag shall be controlled and operated automatically by the approach of trains, in such manner that only approaching trains shall operate the signal.

2. That any order of the Board providing for the installation of a highway crossing signal and referring to the *Standard Specifications for Highway Crossing Signals,* shall be deemed a reference to the specification herein approved and adopted. »

New Zealand.

New Zealand occupies a unique position inasmuch as there are no gates, barriers or balanced poles anywhere in the Dominion.

At all crossings a notice board is erected nine feet from the railway bearing the words « Railway — Look-out for engine ».

In addition to this, a sign in the form of a St. Andrews cross is erected approximately 440 feet from the railway on the roads approaching the crossing. The words on this sign are « Railway crossing ». Cattle stops are employed to prevent cattle straying on the line.

At city crossings where traffic is heavy, level crossing keepers are employed, who carry a sign mounted on a pole. This sign is yellow and has painted in black letters the word « Stop ». The letters are outlined with small mirrors so that at night time the wording is illuminated by the reflection from the vehicle lamps. A warning bell is sometimes used in addition.

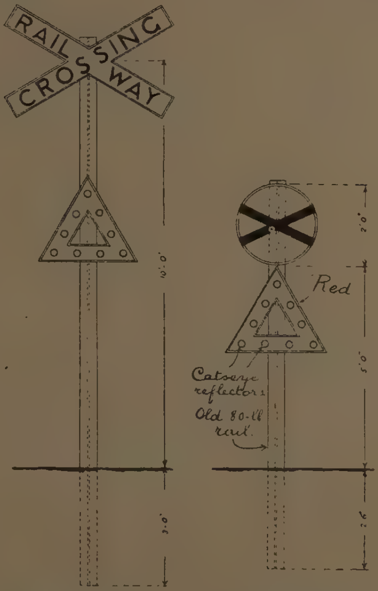
At most of the more important crossings in the Dominion, however, all motorists are compelled to come to a stand before proceeding over the railway, stopping their vehicle at the notice « Compulsory stop » which is erected on a stamped steel standard painted yellow. This arrangement is being rapidly superseded by the provision of audible and visible bell signals, wig-wag signals and flashing lights operated automatically by means of track circuits, but flashing lights much on the American model are to be employed exclusively in the protection equipment of further crossings.

Another form of signal has been used in a few cases. It is called the Pearson signal and consists of two arms pivoted on a common centre. At the ends of the arms electric lights are fixed so that when these arms revolve a moving circle of light is shewn to the motorist. There is also a gong attached which is struck by loose rings at the ends of the arms so that the signal is both audible and visual. The arrangements with regard to the expense and upkeep of these protective devices differ fundamentally from those in other countries. The advanced warning St. Andrews cross is supplied and maintained by the various local bodies throughout the Dominion. The « Compulsory stop » signs and crossing notices placed close to the crossings are paid for and maintained by the Railway Department, except on main highways, where half the cost is borne by the Highways Board. Automatic wig-wags and flashlights on main highways are paid for in equal proportions by the Railway Board and the Highways Board both as to first cost and upkeep. Such devices, erected on the roads throughout the country, are installed and maintained by the Railway Department.

Australia.

In Australia gates interlocked with signals are considered as forming a substantial physical barrier and are regarded as the safest means of guarding level crossings. Vertical-bar type pneumatically-operated gates are in use where signal cabins are adjacent to road crossings and where more than two lines exist, thus rendering the width of the crossings too great for other types of barrier.

Track-circuit controlled flashing light signals, and wigwags, but of a revolving type, are also employed, drawings of which are illustrated (figs. 9 and 10).

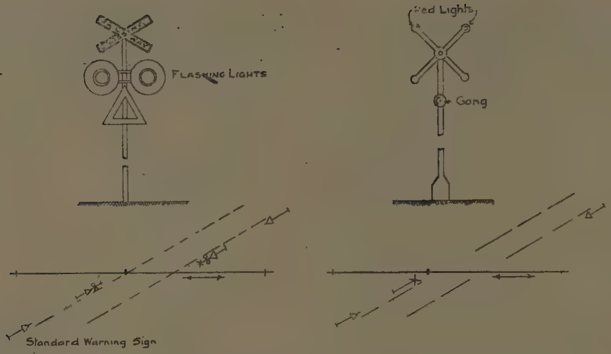


Sign used at open level crossings. Located 10 feet.

Advance warning sign. Located 100 yards.

Fig. 9.

New South Wales has a standard system in operation agreed with the Road Authorities that at all open level crossings, i.e., those not equipped with gates or booms, a notice with cross-arms shewing « Railway Crossing », and with a red triangle underneath, fitted with catseye reflectors, is provided on each side of the line, 10 feet from the nearest rail. These signs are not provided at crossings fitted with gates or booms as the gates themselves when closed against road traffic are considered to give suf-



Flashing light signal (standard). *Wig-wag signal.*

Fig. 10. — Flashing light and wig-wag signals, New South Wales Government Railways.

ficient warning to drivers of road vehicles.

An additional sign, consisting of a white disc with black cross-arms and with red triangle underneath, fitted with catseye reflectors, is provided at open level crossings not equipped with gates or booms, where the approach view is restricted, and in special cases at level crossings provided with gates or booms, where the local conditions are such as to render these approach signs necessary in order to afford adequate protection for road traffic. These signs are fixed at a distance of not less than 100 yards from the nearest rail.

At existing crossings, the road warning signs which are placed 10 feet from the nearest rail are provided, erected and maintained by the railway authorities but the approach signs are only supplied by the railway authorities, and are erected and maintained by the road authority. At new level crossings over existing lines, both the signs at the crossings and the approach signs are to be supplied, erected and maintained by the road authority.

Wig-wags are electrically operated and are set in motion by the approaching train on arrival at a predetermined point, usually about 4 000 feet from the crossing.

South Africa.

The Union of South Africa decided in 1927 to set up a committee with representatives of the railways and public bodies to go thoroughly into the question of protection at the level crossings and to examine the methods in use in order that better protection could be adopted for the type of level crossing which would satisfy both the public and the railway authorities. The result was a seventy-two page report presented to both Houses of Parliament on 27th December, 1927, out of which a definite standard for all future practice has been evolved but it will of necessity be many years before this standard will be universally in use, there being still various types of protection devices in use, in what were different provinces prior to the Union. Incidentally it is of interest to note that the wig-wag was demonstrated in South Africa prior to the appointment of the Committee and was tried by the South African Railways, but discarded because of unsatisfactory working, and this device is no part of the standard adopted. There is no classification of roads in the Union but there is a classification of crossings as follows :

Class 1. Unimportant level crossing.

Class 2. Level crossings where motor traffic is heavy.

Class 3. Level crossings where the provisions of class 2 are not considered adequate from the point of view of visibility and density of traffic.

The form of protection at class 1 crossings is an advanced sign in the form of a St. Andrews cross painted aluminium colour mounted on a telegraph pole thir-

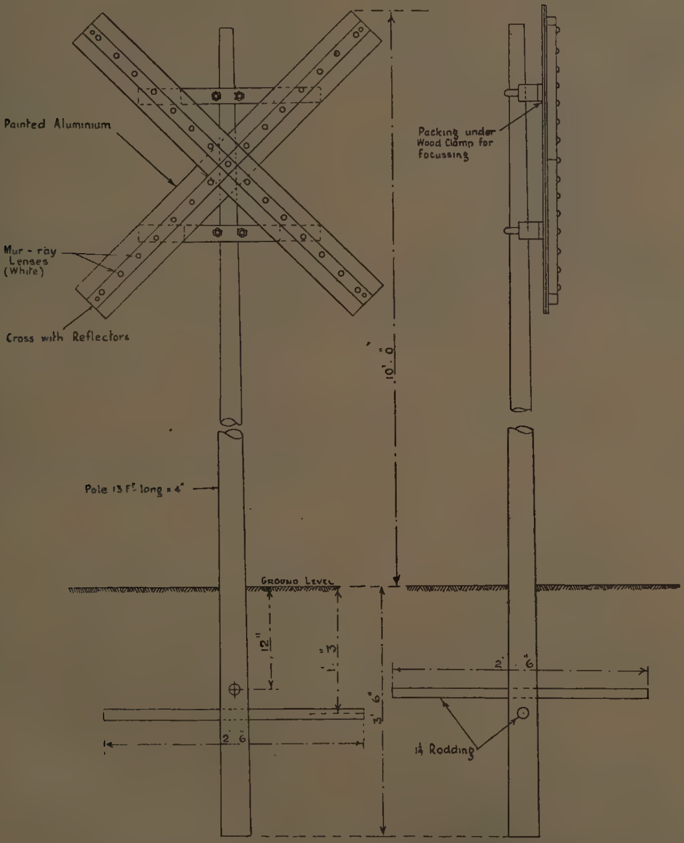


Fig. 11. — Advance warning sign for level crossing protection, South African Railways and Harbours.

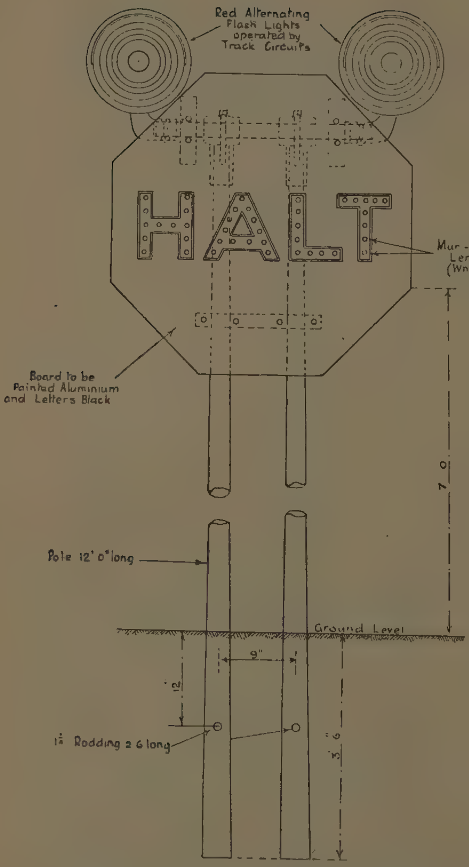

Red Alternating Flash Lights operated by Track Circuits
HALT
Mur-ray Lenses (White)
Board to be Painted Aluminium and Letters Black
Pole 12' 0" long
Ground Level
9"
1½ Rodding 2 6 long

Fig 12. — Flashing lights for level crossing protection, South African Railways and Harbours.

teen feet high. These signs are fixed one hundred yards from the level crossing on the left hand side of the road and so placed as to face direct to approaching road traffic in each direction. At the level crossing itself there is a close-up sign painted aluminium colour with the letters « Halt » painted black the board being mounted on two poles twelve feet long.

The protection to class 2 roads is the same as to class 1 with the important addition that each arm of the St. Andrews cross in the advanced sign, is fitted with mur-ray white reflector lenses seven along each arm of the cross ; these lenses are focussed by means of an arrangement provided, so as to reflect to the driver of an approaching car the light from his own head lights, and each letter in the word « Halt » in the close up signal is fitted with mur-ray red reflector lenses focussed in the same manner.

The protection of class 3 roads is a variation of class 2 to the extent that the close up signal is illuminated with white mur-ray lenses instead of red as in class 2, and two red lights are superimposed flashing alternately and operated by a track circuit. These flashing lights are focussed to throw their beam along the roadway.

Pole gates with or without screens and constructed of lattice steel are also used in conjunction with the lights as in class 3. They are always operated mechanically either by a signalman or a gatekeeper, but no female gatekeepers are employed.

India.

The Railway Department of the Government of India issue very comprehensive requirements for the protection of crossings on the railways. Gates are the principal protection prescribed ; they are fitted with red lights to the road and white to the railway when they are closed across the road, with white to the road and red to the railway when open for road traffic. All gates, if within station limits, are interlocked with station signals or if outside station limits with special signals provided on both sides of the crossing except in special cases under rules approved by the Senior Governement Inspector of Railways.

The lights must be so sighted as to be visible for 100 yards from each gate. All crossings are classified by the Government as being either « special », A class, B class, C class and D class, and the protection for each is set out in schedule form, the number of gatemen to be provided for each class being three, two, one, one, and one, respectively. Advanced warning signs are only required in the special and the A and B classes and consist of a conventional sign erected where considered necessary by the Road Authorities 100 yards from each gate and placed close to the edge of the road on the left of vehicles approaching the crossing. For the minor classes, chains are used instead of gates.

It is to be noted that nowhere in the Dependency are audible or visual signs in use and there is a complete absence of the « unique » wig-wag device which is so characteristic of the northern half of the American continent.

In Ceylon the level crossings on the Government Railways are protected generally by gates interlocked with signals. In a few instances warning bells are used in addition and, where gates are not interlocked, gatemen are employed. Flashing lights and the more modern protective methods are still in the experimental stage.

Egypt.

Important level crossings on the Egyptian State Railways are usually provided with swing gates, rolling gates or barriers with screens, such gates and barriers being interlocked with signals and controlled from a signal cabin where possible. If not so controlled, they are operated manually by gatekeepers. No devices such as wig-wags or flashing lights are in operation but an advanced warning sign in the shape of a St. Andrews cross set on a disc, the whole of which is thickly studded with 240 red catseye reflectors is being adopted to attract the attention of drivers of motor vehicles. This device which is pitched so as to reflect the head lamps of approaching vehicles is easily the most striking which has been met with in the countries under review.

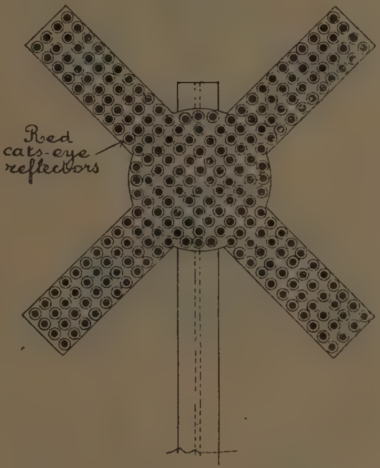


Fig. 13. — Advance warning sign, Egyptian State Railways.

Crown Colonies.

The level crossing problem in the Crown Colonies of the British Empire is not acute, road traffic not being heavy and generally speaking requirements are met by the provision of gates or poles within the cities and warning boards outside.

United States of America.

The United States have such a varying density of population that it is quite understandable that no uniformity of practice has been evolved. Moves in the

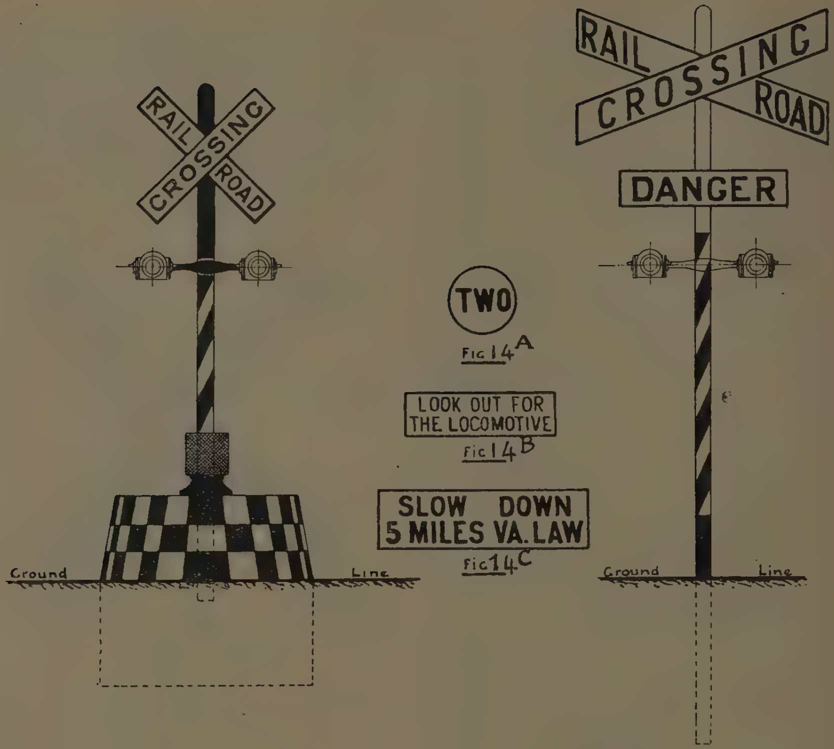


Fig. 15. Fig. 14.

Figs. 14 and 15. — Standard flashing lights, Pennsylvania Railroad, U. S. A.

Signs in accordance with fig. 14 used in the States of Pennsylvania, Maryland, Illinois, Michigan, Delaware, Columbia, Kentucky, Ohio. Within the State of New Jersey the plate marked DANGER is omitted.

Within the State of New York fig. 14 may only be used where flashing lights are not required. If flashing lights are required fig. 15 is employed. Within the State of Indiana a plate shewing the number of roads must be added (fig. 14A). Within the State of West Virginia the DANGER plate is replaced by fig. 14B.

Within the State of Virginia the DANGER plate is replaced by fig. 14C.

At all crossings where executive authority is given the flashing lights are added.

Whenever the sign is required in the centre of the road fig. 15 is employed.

direction, however, are continually being made by such bodies as the American Railway Engineering Association, the American Railway Association, etc., in conjunction with the Interstate Commerce Commission.

Generally speaking, the advance warning sign which is placed on the highway at a distance from the crossing is the sole attempt at uniformity at the present time, but even here there is considerable difference in practice in the various States both in installation, maintenance and location.

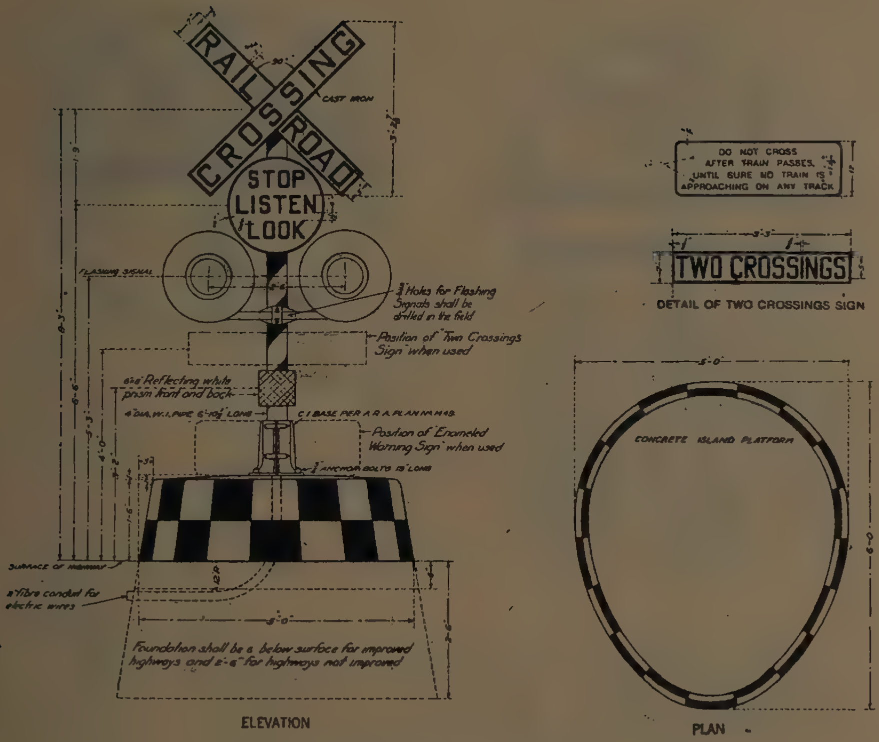

RAIL ROAD
CROSSING
CAST IRON
STOP
LISTEN
LOOK
FLASHING SIGNAL
¾" Holes for Flashing Signals shall be drilled in the field
Position of "Two Crossings Sign" when used
6×6" Reflecting white prism front and back
4" DIA. W. I. PIPE 6'-10½" LONG
C I BASE PER A R A PLAN No 1148
Position of "Enameled Warning Sign" when used
¾" ANCHOR BOLTS 18" LONG
SURFACE OF HIGHWAY
2" Fibre conduit for electric wires
Foundation shall be 6' below surface for improved highways and 2'-6" for highways not improved
ELEVATION
DO NOT CROSS AFTER TRAIN PASSES UNTIL SURE NO TRAIN IS APPROACHING ON ANY TRACK
TWO CROSSINGS
DETAIL OF TWO CROSSINGS SIGN
CONCRETE ISLAND PLATFORM
PLAN

Fig. 16. — Standard road crossing sign with flashing lights, Reading Company. Sign located in center of highway.

The United States Department of Commerce inaugurated the National Conference on « Street and Highway Safety » in 1924, when President Hoover was the Secretary, and fixed an annual meeting in May for the purpose of examining and co-ordinating the practice of highway traffic, protection, and regulation. All interested bodies, including the National Association of Railroad and Utilities Commissioners participate in the deliberations.

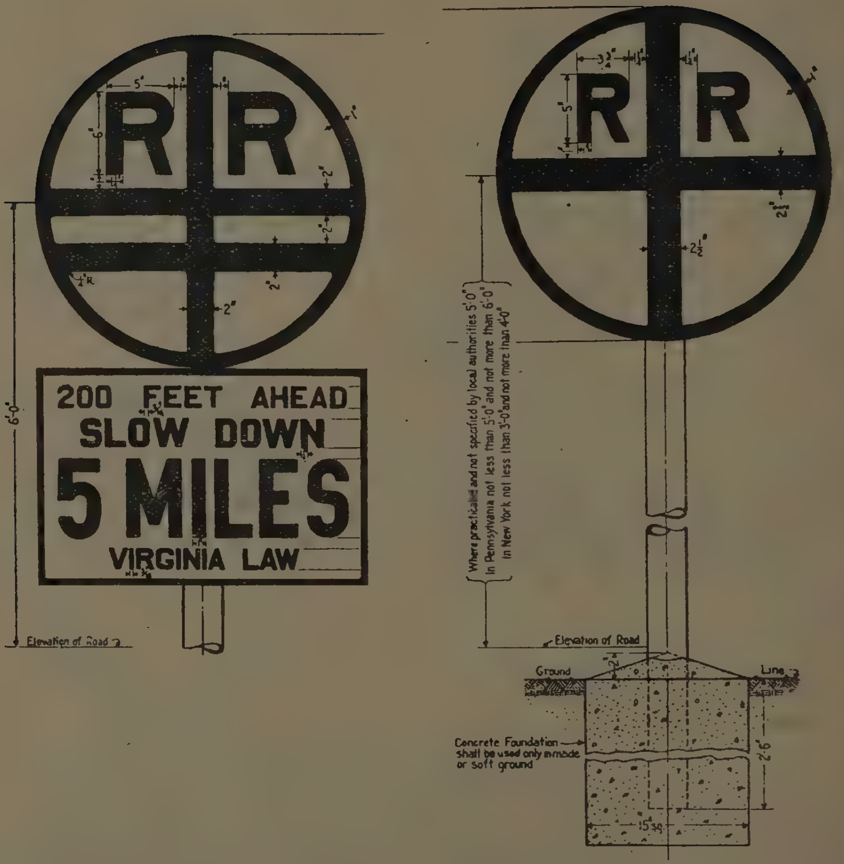
The American Railway Association, which speaks for the united railway interest, is represented by its « Committee on Grade Crossing Protection » in order to frame its own proposals with the findings of the National Conference. Its programme is in three parts :

1. Unification of State motor vehicle legislation.

2. Unification of municipal traffic ordnances.

3. Unification of streets and highway traffic signs, signals and markings.

All of these have been drafted and the « Safety Code of Colours for Traffic


RR
200 FEET AHEAD
SLOW DOWN
5 MILES
VIRGINIA LAW
6'-0"
Elevation of Road
5"
6"
2"
2"
RR
3 3/4"
5"
2 1/2"
Where practicable and not specified by local authorities 5'-0"
In Pennsylvania not less than 5'-0" and not more than 6'-0"
In New York not less than 3'-0" and not more than 4'-0"
Elevation of Road
Ground
Line
Concrete Foundation shall be used only in made or soft ground
2'-6"
15"

Front elevation of sign for use within the State of Virginia.

Front elevation of sign for general use.

Fig. 17. — Standard approach warning signs, Pennsylvania Railroad, U. S. A.

Signals » has been adopted as the national standard for the United States by the organisation of the American Standards Association. Its sponsors are the American Association of State Highway Officials, the United States Bureau of Standards (Department of Commerce) and the National Safety Council (representing the National Engineering Societies).

United States standard road markers and signs have been drawn up by the American Association of State Highway Officials but the American Standards Association have not given them standing.

The methods of protection at present

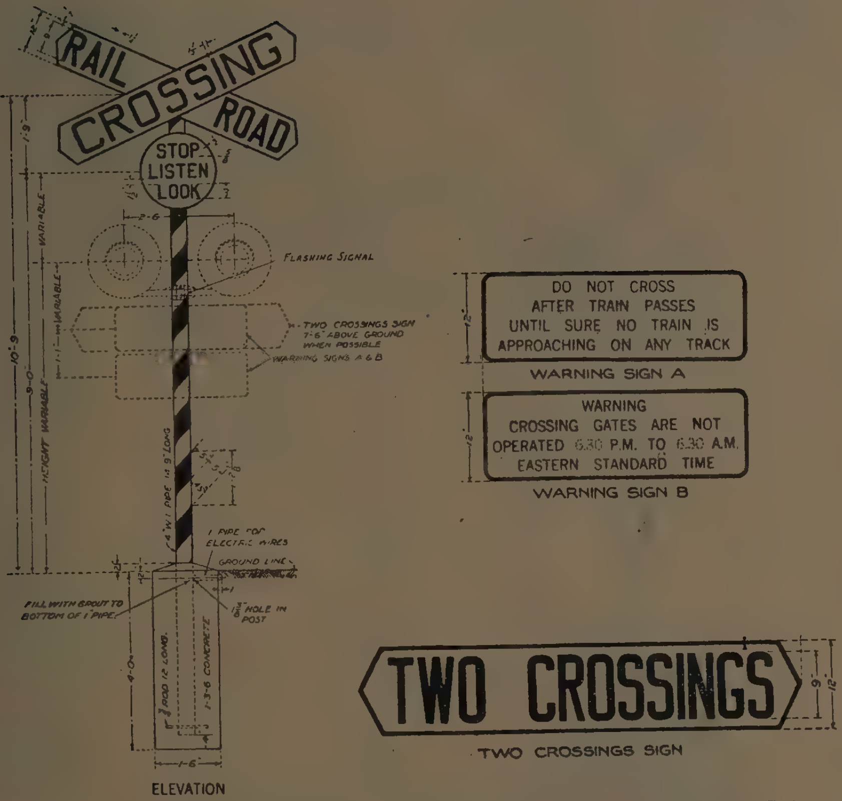


Fig. 18. — Standard road crossing sign at side of highway, Reading Company, U. S. A.

in use are for crossings in the cities, generally to have gates, but gates are rarely found at points outside the city limits. In some cases gates are supplemented by watchmen, audible warning devices such as a gong or locomotive type bell, automatic wig-wags, flashing light signals, a combination of audible signals and watchmen, and the use of both audible and visual signs.

The installation of any of the above depends on several variable factors, amongst which are the amount of road traffic, the physical character of the crossing, (that is, whether or not the view of approaching trains is restricted), and the class of highway, whether trunk line or secondary roads.

The use of watchmen is confined entirely to street crossings in cities.

Audible signals are not favoured at busy crossings in residential districts, due to the annoyance from the almost continual ringing of the gong or bell.

A wig-wag signal is a visual signal which may be fitted with a bell or gong if required.

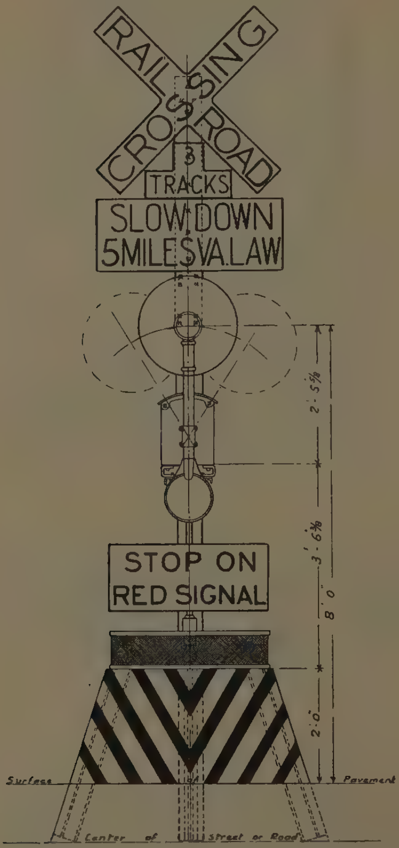
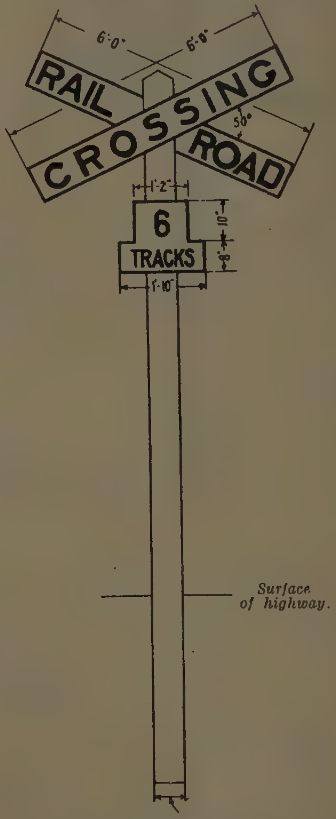


Fig. 19. — Wig-wag signal, Norfolk and Western Railway, U. S. A.

The swinging disc or arm is operated by a motor, or by a track circuit when a train is approaching a crossing.

The flashing signal is a horizontal alternately flashing red light which may be attached to a higway signal or installed separately. As the flashing red light is very arresting to the eye it provides



Not less than 6 inches.

Fig. 20. — Highway crossing recommended by American Railway Engineering Association, U. S. A.

Note:

Paint blades white with black letters and border.

Locate signs at such points as will admit of the best view by persons approaching the crossing.

Board indicating number of tracks to be used where there are two or more tracks.

The plan shows the sign mounted on a wood post. When a post of steel or concrete is used the dimensions of the post should be suitable to the material employed.

more protection than the usual type. The light flashes about thirty times a minute as a minimum, with forty as a maximum, and the lights are usually fixed from twenty to forty feet away from the crossing.

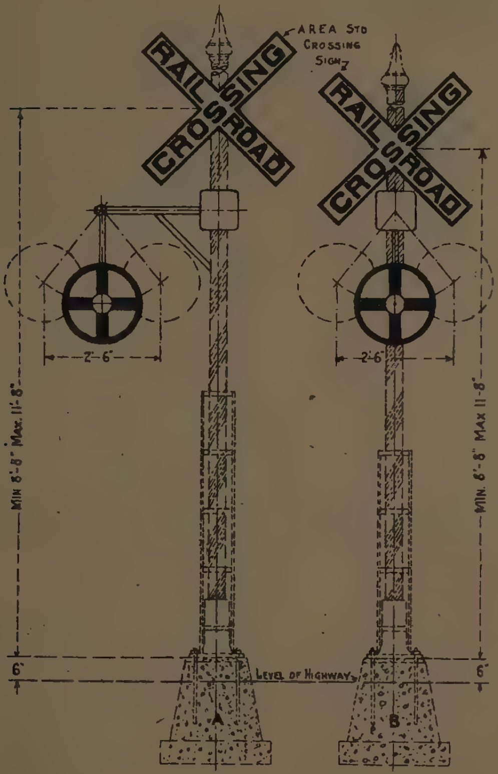


Fig. 21. — Wig-wag signal recommended by American Railway Engineering Association, U. S. A.

With the growing importance of the grade crossing question in America, the increase in types of crossing designed and promoted by engineering firms has been enormous, but it is recognised that uniformity of practice and standards in signs is of primary importance though frequently this objective is lost sight of in the glamour of a new invention. In this connection it is of interest to record only a few of the special types of grade crossing protection devices examined

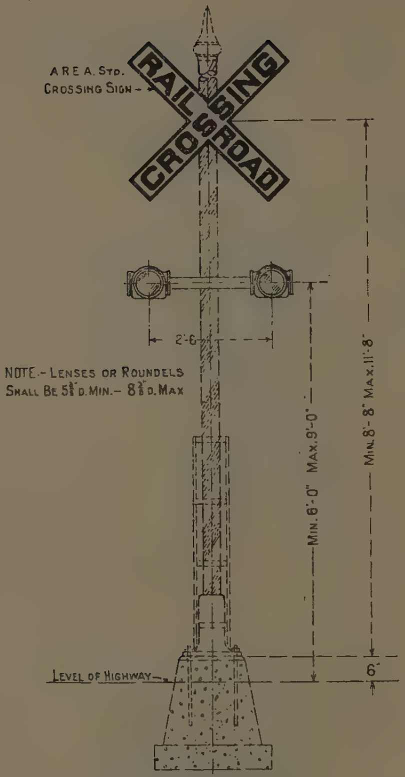
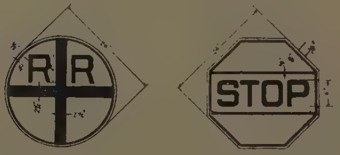

A R E A. Std. Crossing Sign
RAILROAD CROSSING
2'-6"
NOTE.- Lenses or Roundels Shall Be 5⅜" D. Min.– 8⅜" D. Max
Min. 6'-0" Max. 9'-0"
Min. 8'-8" Max. 11'-8"
6"
Level of Highway

Fig. 22. — Flashing lights recommended by American Railway Engineering Association, U. S. A.



Advance highway crossing sign.

Stop sign to be used when required by law or regulation.

Fig. 23. — Advance warning signs recommended by American Railway Engineering Association, U. S. A.

during 1930 by the Committee, which recommended that they be laid on the table and received as information :

1. Safe-T-bar automatic highway grade crossing barrier of the « Highway Guardian ». — This is of the gates and lights type of protection. It consists of a yielding barrier arm which can be controlled manually, automatically, or both.

2. Foard safety device. — This consists of lights, gates, and train control. It is a device which automatically stops trains if obstruction is on the crossing after the gates have been lowered.

3. Yielding barrier gates. — This si an automatic yielding barrier gate which rises and lowers vertically on a horizontal plane.

4. Max Friedland method. — This consists of gates, lights, bells and train control ; the automatic train control device is controlled by the position of the crossing gates which once lowered cannot be raised until the train is clear of the crossing.

5. The Hubbard smoke signal. — This is also known as the auto highway signal. It consists of a pipe post set in a concrete foundation. The post supports the operating mechanism consisting of a magazine to hold a supply of smoke flares, one of which is released and ignited by an electric spark when approaching trains enter the crossing area. The smoke thus generated is thrown across the highway on each side of the railway crossing.

6. Minor super-safety gate and signal system. — This operates automatically with the approach of a train. Warning is given through the medium of a siren which is immediately followed by a visible signal to highway traffic which, in turn, is prevented from entering the danger zone by the lowering of the gate. Signals are also operated for the benefit of train crews by semaphore display of

a red signal until the approach of the train sets in motion the foregoing operation which, in turn, opens the track by a signal for through movement of a train.

From these proposals it will be seen how very insistent private enterprise is in America in providing commercial protective devices, although it is doubtful if many of these could ever hope for more than a purely local adoption.

Gates are much out of favour in America and it will be seen from table IV that there is a gradual but ever increasingly progressive elimination of this form of protection. The American Railway Engineerning Association after exhaustive enquiries into all forms of level crossing protection observes in its report that it is recognised that even when operated by a gateman, he has to depend on his vision and hearing to tell when trains are approaching and on his judgment as to his action in operating the gates — this requires a continuously alert condition of mind and in foggy weather the situation is particularly hazardous, as, if the engineman fails to sound his whistle the gateman has to depend on limited vision alone. Gates are frequently run into and when rising booms are used, vehicles are at times pinned down as they are lowered, resulting in damage to both gates and vehicles, and generally, responsible opinion in America is that this kind of protection is not satisfactory in that it conveys a false sense of security to those using the crossing and may result in serious injury.

The same report, in speaking of crossing watchmen describes them as more or less a relic of the horse-drawn vehicle days when positions were often filled by incapacitated employees who were able to control the leisurely traffic of that time, and claims that with the advent of automobile traffic, a watchman, to be effective, should be alert mentally and physically and vested with police power to regulate traffic and to deal with reckless offenders who may attempt to cross tracks ahead of trains in spite of warnings as to the danger of so doing.

Therefore, decision has been reached by the American Railway Engineering Association that the automatic visible signal of the wig-wag or flashing type gives the most efficient protection and for the following reasons :

1. It is automatic and does not depend on the eyesight or hearing of a watchman or gateman to give warning.

2. The failure of an engineman to blow a whistle has no effect on the signal, as action is immediate as soon as a train occupies a circuit.

3. Weather conditions have no material effect on it.

4. Signals are easily seen and there is no mistaking the sign given as sometimes happens in the case of crossing watchmen.

5. At grade crossings protected by gates or watchmen, where protection is intermittent or where the protective devices are not operated the full twenty-four hours, a sign is usually employed on which is shewn the hours the protective device is not in operation or the watchman is not on duty; wig-wag or flash-light signals or automatic gates are operated continuously and do not require such a sign.

American practice, therefore, excluding ingenious but complicated devices which have merely a local interest, is :

a) The advanced warning sign located anything up to 600 feet from the crossing, having generally in conjunction with it a 24-inch metal disc bearing the letters « R. R. » mounted on a metal standard, at the crossing itself ;

b) Wig-wag signs or flashing lights at important crossings ;

c) If unimportant, a cross buck sign of two blades about 6 to 8 feet long at from 50 to 90 degrees with each other mounted on metal points, the blades carrying the words « Railway Crossing », « Look out for Cars » or « Look out for Locomotive » as the case may be. With regard to automatic wig-wags and flash light signals there appears to be a considerable difference of opinion as to the merits of the two types of protection. Both appear to answer the requirements demanded, and the night indication is of equal value in both. It would appear that the Mississippi river marks the boundaries of the partizans of each type; to the east of the river flashing signals seem to hold the field, while to the west of the river, wig-wags are more in favour. Great pressure has been brought to bear upon the Committee to comprise and recommend as standard practice that the railways east and west of the river shall adopt the flashlight and wig-wag respectively, but it has been recognised that this is not the proper solution to the problem, and without doubt the decision of the Board of Railway Commissioners of Canada in adopting the wig-wag as the standard type of signal in that country has had much to do to influence this decision, as the desirability of uniformity of method throughout the North American Continent is recognised.

The question of location of the wig-wag or flashing light signal is another question upon which opinion is much divided, one school favouring a situation on the right hand side of the road close to the paved portion of the highway and another in the centre of the roadway. The advantages claimed for the signal being in the centre of the roadway, viz., that it divides the traffic, enforces reduced speed, and avoids any question of the automobilist seeing the sign, has appealed to many engineers. The principal objectors are the various State Highway Commissioners who in general oppose the obstruction of the middle of their high speed roads and insist on the placing of these signs and signals on the side.

In some States the provision of a « whistle » post is prescribed by law, generally about 1/4 of a mile away from the crossing, and engine whistles are to be sounded at that distance. It follows that with a train moving at 60 miles per hour, the whistle sounds about 15 seconds before the crossing is reached; with higher speeds the time is correspondingly less, and with slow trains the sound might never reach a fast moving motorist. Moreover this method of additional protection is not very reliable as in stormy and inclement weather, with a high wind blowing away from the crossing, the whistle might conceivably not be heard at all. With flashing signals, generally the time of operation is 20 seconds before the arrival of the fastest train to the crossing ; too long an operation is considered undesirable, doubtless owing to the temptation it gives to « cut across ». The height of the lamps is from 6 to 9 feet above the surface of the road and they are constructed with a space of 2 ft. 6 in. between the centres, the flashing rate being about thirty a minute with a range of at least three hundred feet in bright sunshine, and having a spread of beam of about three degrees on each side of the axial line. The lenses are about 6 to 8 inches in diameter.

With wig-wags the swing of the disc is 2 ft. 6 in. between the extreme points of its travel, and the speed about 30 to 40 times a minute backwards and forwards. The discs are fitted with a lamp in the centre as powerful as the « flashing » ones, and this lamp automatically lights up when the disc swings.

With regard to the bell attachment which is shewn on the diagrams, its value is purely relative, undoubtedly in foggy or snowy weather the audible signal has a great value, but generally speaking, the penetrative power of sound is less than that of vision, whilst many road vehicles carry with them a vast quantiy of sound which if taken in conjunction with a high wind would of necessity obscure the audible signal. Audible signs are recognised now as only of value to supplement visual signs.

Japan.

Japanese practice does not present quite the same clear cut policy as is characteristic of the United States, Canada or Great Britain. Arresting devices such as gates or balanced poles are relied upon for all first and second class crossings, but such gates are not interlocked or controlled by a signal and are operated by crossing keepers either male or female. Flash lights, bells or lamps are used, either in conjunction or separately with barriers and are operated through a track circuit.

Figure 24 shews the advanced warning signs employed where necessary at unprotected crossings (form A), and at second class crossings (form B).

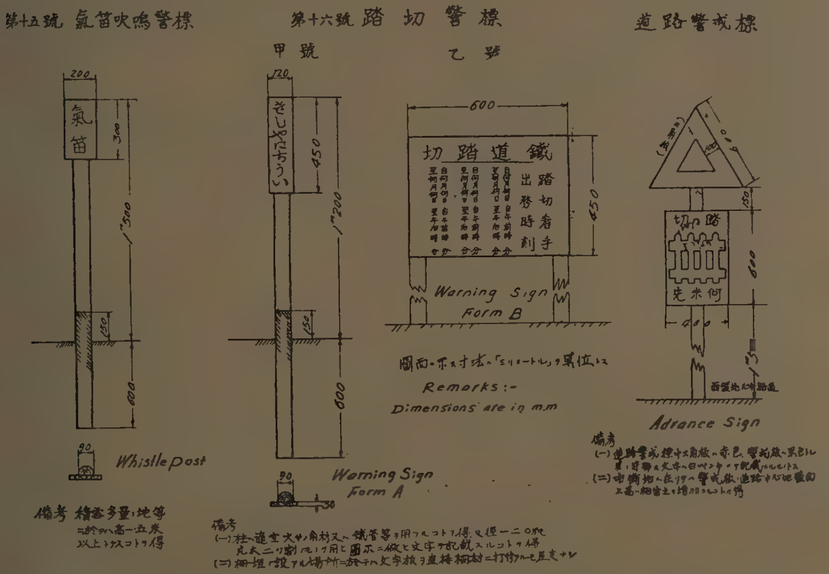

第十五號 氣笛吹鳴警標
氣笛
200
300
1500
150
600
90
Whistle post
備考 積雪多量ノ地等ニ於テハ高一五米以上トナスコトヲ得
第十六號 踏切警標
甲號
乙號
120
さしきちうい
450
1200
150
600
90
30
Warning Sign Form A
備考
(一)柱ハ適宜大サノ角材又ハ鐵管等ヲ用フルコトヲ得又径一二〇粍丸太二ツ割ハヲ用ヒ圖示ニ倣ヒ文字ヲ記載スルコトヲ得
(二)柵埋ノ設アル場所ニ於テハ文字板ヲ直接柵材ニ打付クルモ差支ナシ
600
鐵道踏切
踏切看手出務時刻
450
Warning Sign Form B
圖面ニ示ス寸法ハ「ミリメートル」ヲ單位トス
Remarks:-
Dimensions are in m.m
道路警戒標
150
600
踏切
先米何
Advance Sign
備考

Fig. 24. — Advanced warning signs employed in Japan at unprotected crossings.

China.

Details with regard to China are incomplete, the only information available being with respect to Manchuria and part of the Kwantung leased territory served by the South Manchuria Railway Company, and the Pekin Hankow Railway in China proper. Generally speaking, in China and Manchuria control and classification of the roads is not in a forward state. The method in most common use for protection of crossings is the balanced pole with or without screen attachment and operated by watchmen. As compared with Europe and America there is very little road motor traffic in China and less in Manchuria.

South America.

The Republics of South-America are not nearly so advanced in their treatment of this question as is the northern half of the Continent. In many of the countries wig-wags and flashing lights have not passed beyond the experimental stage.

Uruguay relies upon gates and barriers as the main form of protection, and these for the most part are operated manually by female or male gatekeepers, there being only two which are mechanically controlled by the signalman from his cabin, the power meantime being hydraulic, to be converted shortly to pneumatic power.

At only a few crossings in Uruguay are audible or visible signs in use and they are in conjunction with the barriers or gates. This form of protection consists of two red lights facing the roadway which alternately blink during the whole of the time crossing barriers are closed to road traffic.

They are set in motion by the barrier guard in lowering the barriers, before which, by means of a press button, an electric bell is rung which continues ringing until the barriers are finally lowered and closed to the road.

There are a few crossing gates which are interlocked with signals on double track.

The Argentine employs gates and balanced poles shut and locked from the signal cabin at important crossings and balanced poles manually operated by male or female crossing keepers at others, worked either by chain and counterweight or by means of a hand winch.

On the Buenos Ayres and Pacific Railway there is one set of gates operated electrically. This is done by an electric pump which is arranged to force oil against one side or other of a vane which works in a suitably designed chamber. This vane moves the usual mechanical connections to the gates in the direction desired by the signalman. The signalman is provided with control levers interlocked with the signals. These switch in the motor and operate a slide valve to control the entrance of the oil to that side of the vane which will cause the gates to move in the direction required.

This arrangement has given satisfactory results and relieves the signalman of a considerable amount of heavy work, which is an important factor where both street and railway traffic is intense. It has also been found that the operation of the gates is slightly quicker than with the mechanical gear.

There are no screens to the balanced poles and this arrangement applies also to Colombia.

In Brazil where mechanical signals exist mechanically operated gates and wickets are provided, and audible and visual signs are given before the gates are closed to the road. These signs are fixed about 50 yards from the crossing and consist of an alarm gong and red and green lenses operated as follows :

On the gate stop being reversed to move the gates to close across the road, the gong rings and the green light changes to red, which continues until the road is again clear ; the gong ceases to ring when the gates are closed. Five sets of sound-light devices are about to be fixed at unattended crossings of 2nd class roads with double main lines of railway, where ordinary occupation crossing gates exist. These devices consist of a red flashing light and alarm gong, mounted on a standard to be fixed in the roadway not more than 50 meters either side of the level crossing. A train approaching the crossing from either direction will actuate an electric treadle fixed one kilometre distant, which, through relays, will operate the light and gong simultaneously. These will continue to function until the train operates a second treadle fixed on the far side of the crossing. The devices will form the only protection at crossings and will not indicate the number of lines to be crossed.

Summary of section.

In reviewing the practices in operation in the various countries it must be kept in mind that public road-railway crossings exist under statutory authority. As regards the earliest of them, and some of them are now 100 years old, they were probably regarded at the date of their construction as not imposing in their use any material effect in the free use of roadways. It is obvious, indeed, from the restrictions imposed on the earlier railways by legal enactments that these early railways had to some extent to give way to the requirements of the road user. What has entirely changed the whole outlook with regard to them is that the use made of roads today is fundamentally different from what it was when the early level crossings were constructed. Many new railway schemes today would, by law, doubtless have to provide overbridges where their predecessors without any objection were allowed to construct level crossings. It has always been realised, however, from the very beginning of railway enterprise that where railways crossed public highways some provision for the safety of the public using the road had had to be made. It is somewhat striking to observe how, with the gradual trend of development in appliances for protection at crossings, certain countries, like Great Britain and New Zealand, have improved and developed their original device, viz., gates, with which they originally provided protection, but, on the other hand, any such procedure may have been more or less inevitable in view of the fact that many of the early Acts applying to railways are still in force. This may explain why Great Britain in particular has improved and developed the use of gates as a crossing protection whereas in America the modern form of light and sound protection without gates is more common. It has to be borne in mind that America never did have a road system in the early days of its railways in the same sense as Great Britain had. In fact in America the early roads were « rail-roads », there virtually being no other roads at the date of the first railway construction in America, and hence the retention of the word « railroad » in America in describing what is elsewhere designated « railway ». The designation « highway » is used in America instead of « road » in the older countries. Thus America has never been trained to the gate type of protection, but has suffered from a confusion of systems, the result of varied types of warning appliances of no order or uniformity. It is even now reserved to each State to make its own laws and regulations as to the extent to which safety appliances are to be introduced and as to the description of protective devices to be used, with the result that a motorist travelling from one State to another may meet varying types of protection at each level crossing he encounters, with the resultant confusion which such a state of things inevitably brings about.

Canada.

Canada seems to have followed more closely the example of Great Britain, and, generally speaking, one finds a more uniform type of protection there. It is laid down, for instance, by the Board of Railway Commissioners, that there shall be warning signals at all level crossings. The whole problem of railway crossing protection has been dealt with in Canada in recent years on a very comprehensive standard, the objective which is set out to be achieved being the elimination of many highly objectionable crossings. The steps taken are briefly as under :

In 1909, a « railway grade crossing fund » was created by Act of Parliament in Canada, to which $200 000 was to be credited each year from the consolidated revenue fund for the purpose of « aiding in the providing by actual construction work, of protection, safety and convenience for the public in respect of highway crossings of the railway at rail level » in existence on the 1st April, 1909. Sums from the fund were to be applied solely towards the cost, exclusive of maintenance and operation, of actual construction work, and were not to exceed 20 % of the cost in the case of any one crossing of actual construction work, in providing such protection, safety and convenience. The sum payable at any crossing was not to exceed $5 000, nor could any such grant be applied to more than three crossings in any one municipality in any one year. Finally there was the provision that the grant could not be used more than once in the case of any one crossing. Provision was also made for contributions to the fund from any of the provinces, and no restrictions were laid down as to whether crossings were to be replaced by over-line or under-line bridges or by diversion, provided that the number of railway tracks did not exceed four. The term « municipality » covered a city, town, village, county or township.

In 1914 the annual grant of $200 000, originally limited to a five-year period, was extended for a further five years, and at the end of this latter period, that is to say in 1919, this provision of the Railway Act was amended somewhat in the following sense.

In future sums appropriated to the railway grade crossing fund were to be applied solely towards the cost of actual construction and the percentage limit raised to 25 % in the case of any one crossing, and was not to exceed $15 000, with a maximum of six crossings in any one municipality each year ; where a province subscribed to the fund it possessed the right to apportion its own contributions. The amendment specifically included « protection, safety and convenience for the public », and the period of the annual grant was extended for a further ten years, that is to say until 1929. The next change occurred in 1926 when the maximum percentage grant in and from the fund was raised to 40 %, with a maximum of $ 25 000 per individual crossing.

During 1928 a further amendment was passed, so that contributions from the fund could be made towards the elimination of those crossings constructed since 1st April, 1909, but not applicable to any to be completed after 1st April, 1929, unless subject to a special agreement approved by the Board of Railway Commissioners, between the railway company and the municipality or person agreeing with the railway to bear a portion of the cost of actual construction work for the protection, safety and convenience of the public in respect of such crossing. The maximum grant per crossing was at the same time altered to $100 000 and 40 % of the total cost. In 1929, the period over which the grant was to apply, was continued for a further ten years.

The following table shews the expenditure from the fund from its inception to the end of 1927 :

Expenditure for protection at highway crossings, to which contributions were made from the railway grade crossing fund 1909 to 31 December 1927.

Province.	Railway grade crossing fund.	Municipality.	Railway.	Total.
British Columbia	$ 54 887.83	$ 191 670.06	$ 115 070.88	$ 361 628.77
Alberta.	27 022.53	136 561.94	205 831.98	369 416.45
Saskatchewan.	34 180.18	515 597.10	247 155.35	796 932.63
Manitoba	14 158.72	47 115.53	49 827.94	111 102 19
Ontario.	484 986.00	1 261 445.66	2 173 020.21	3 919 451.87
Quebec.	134 183,96	492 248.10	350 335.28	976 767.34
New Brunswick	24 111.23	30 617.98	41 355.36	96 084.57
Nova Scotia	70 903.91	70 846.60	39 581.79	181 332.30
	$ 844 434.36	$ 2 746 102.97	$ 3 222 178.79	$ 6 812 716.12

Expressed more briefly, 13.6 % of the total spent on level crossing protection over this period was obtained from the « grade crossing fund », 40.29 % from the municipalities, and 46.2 % from the railways, though there is a considerable variation between the percentage figures as between the different provinces.

The lowest percentage contribution received from the fund occurred in Saskatchewan with 4 %, and the maximum in Nova Scotia with 39 %, a difference in general conditions accounting for this variation ; thus, in Alberta, Saskatchewan and Manitoba there proved to be a large number of cases where no prior road crossing rights existed where protection was required, and consequently a large proportion of the cost fell upon the municipality. On the other hand, in Ontario and Quebec the maximum limitation per crossing tends to reduce the average, whereas in Nova Scotia and New Brunswick the majority of schemes involving road diversions or replacement by bridges have not been so costly as to be affected by the limit of maximum contribution.

The table reproduced on the previous page shews that by the end of 1927 the aggregate contributions from the fund had amounted to rather less than $900 000, whereas the total amount accumulated from the annual Government grants should have left a surplus of roughly $1 000 000 at the end of that year. Owing to the extensive level crossing elimination programme embarked upon since 1927, this surplus has not only disappeared, but the commitments of the Board are in excess of the present resources of the fund. It is not, however, as yet known whether the programme projected will have to be cut down or increased grants made to the fund, but the annual report of the Board for 1930 states that contributions have been made towards the elimination of 1 299 crossings since the inception of the fund in 1909 and catalogues the work accomplished as follows :

« From the first day of April, 1909, to the 31st day of December 1930, the Board has ordered contributions from the railway grade crossing fund towards the protection of 1 299 crossings, as follows :

By automatic interlocking plants (street railway protection)	14
By closing crossings	155
By crossings eliminated	84
By diversion and overhead bridge	5
By diversion and subway	3
By diversion to subway	4
By electric bell	208
By electric bell and flashlight	2
By electric bell and wig-wag	367
By electric bell and wig-wag and removing obstructions to view	7
By easing curve on approach to bridge.	1
By gates	125
By gates — automatic	3
By gates and half interlocker.	1
By grade reduction on crossing approaches	6
By footbridge	1
By lengthening ringing circuit of bells.	2
By lighting flash signals	50
By overhead bridges	53
By removing obstructions to view	83
By removing obstructions to view and reducing grade	6
By shelter (watchmen's)	1
By subways	107
By towers (watchmen's)	3
By tunnel	1
By wig-wags	7

« There were 202 highway diversions constructed which made it possible to close 155 crossings, and eliminate traffic from 84 crossings.

» During the year 1930, protection was provided at 153 crossings as follows :

By closing crossings	23
By crossings eliminated	30
By diversion and overhead bridge	5
By diversion and subway	3
By electric bell and wig-wag.	51
By footbridge	1
By grade reduction and widening approaches	4
By grade reduction and improving view.	2
By overhead bridge	6
By removing obstructions to view	16
By subway	11
By wig-wag	1

« There were 35 highway diversions constructed during the year 1930, which made it possible to close 23 crossings and eliminate traffic from 30 crossings. »

It should be noted that during 1930 as a means of relieving unemployment, which began to be acute in Canada in that year, the Canadian Government allocated a special grant towards the fund, amounting to $500 000. This allocation was made from the 20-million dollar unemployement fund, and it is possible that further grants may be made for similar purposes during the existing depression, but no information on the subject is as yet available.

United States of America.

In 1926, a bill was passed by the New York State Legislature known as the Grade Crossing Elimination Act.

This Act authorised the creation of a fund to the amount of 300 million dollars or about £60 000 000 by the issue of State bonds, the fund to be used for the elimination of level crossings in New York State but not those within the city limits of New York, Buffalo or Syracuse for which provision had already been made.

The method of procedure is for the whole cost of any works to be paid from the fund and after completion the State controller determines the shares to be contributed by the railway and local authority respectively.

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New Zealand is entirely without physical barriers at level crossings and relies upon signs and watchmen, while Australia and India, on the other hand, rely chiefly on some form of physical protection similar to that in use in Great Britain, although in Australia flashing signs and wig-wags controlled by the train are in cases being provided. In South Africa, since 1927, the protection has largely taken the form of signs with gates in addition in the more populous areas.

Section IV. — General observations.

The final section of this paper must be suggestive rather than authoritative. Generally it may be said that the percentage of accidents at level crossings is low in most countries having regard to the speed and density of road traffic along the highways of today. The incidence of such accidents as do occur, however, point to the need for continued effort being made by public authorities towards ensuring the safety of the road user — and of the railway passenger — at public road level crossings. This should obviously be done at the expense of the private owner and public road transport companies who should provide the signalling system required for their own or their patrons' safety in the same manner as the railways are compelled by statute to do. The measures taken by Canada in the elimination of level crossings obviously point to some movement in this direction becoming inevitable in that country.

In view of the extent to which motor drivers and their cars pass from one country to another to-day, it may be well worth considering whether a uniform system of level crossing protection common to all countries should not be adopted, but obviously in any such consideration regard would have to be given to the elimination of the diverse practices in certain countries, where in some cases cars pass on the right hand side and in others on the left hand side.

The range of travel of the road user in the early days of railways was largely restricted to his own particular neighbourhood, or to a particular route if long distances were involved. Today there is hardly any limit to the distances which motorists adventure upon, and the advantages of common practices not only at level crossings but in the use of the road generally are obvious.

The further question arises as to the extent to which road signs or road signals as opposed to railway signals only should be instituted for the protection of level crossings. In Great Britain the Ministry of Transport, the Automobile Association and the Royal Automobile Club have done something towards the provision of roadway signs which give warning to the motorist of his approach, not only to level crossings but to other dangerous features in the road contour. These do not so far take the form of audible signals, but are purely of a visual type. In America and Canada the types of light and sound protection described are more of the character of road signalling proper than anything to be found in Great Britain where the railways from their earliest beginnings had thrown upon them the onus of crossing protection.

[621. 33]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

XIIth SESSION (CAIRO, 1933).

QUESTION V:

Electrification of railways from an economic point of view. Selection of sites for generating stations. Choice of the kind of current. Safety precautions, etc.

REPORT No. 1

(America, Great Britain, Dominions and Colonies, China and Japan),

by S. WITHINGTON,
Electrical Engineer, New-York, New Haven and Hartford Railroad, Newhaven, Conn. (U. S. A.).

I. — ELECTRIFICATION OF RAILWAYS FROM AN ECONOMIC POINT OF VIEW.

In considering railroad electrification, as in all other phases of railroad operation, or indeed in any branch of human activity, the advantages or economies (direct or indirect) must outweigh the disadvantages or expenses, if any project is to be justified. In briefly analyzing the problem in the present report, the limitations and sources of expense chargeable to electric operation will first be discussed and later the various sources of economy or other operating advantages. A list of a few of the characteristic electrification installations in various countries covered in the report is presented, together with a brief analysis of the reasons governing the decision to electrify in each instance (see Appendix A).

A questionnaire was prepared and issued to member railroads of the International Railway Congress Association. The returns were not sufficient for tabulation, but the data received have been as far as practicable incorpored in the text of the report.

It is quite impossible to present any general quantitative statement regarding the economies of railroad electrification which would not be misleading. Conditions of fuel supply, labor, equipment and operation vary greatly in different parts of the world. There is indeed a great deal of diversity in different parts of the same country, and there may even be radically different conditions on neighboring railroads. Furthermore, in any given locality, the conditions are often subject to very considerable changes over even relatively short periods of time. For these reasons, quantitative figures will be avoided and general statements only will be presented.

It has been assumed that any analysis of the internal combustion engine as applied to railroad motive power is outside the scope of the present report, and that type of equipment will therefore not be discussed in any way.

Capital charges.

Perhaps the most important charges against electrification are those wherein the expenses are entirely superimposed upon the costs of steam operation. These include mainly capital charges, (interest, depreciation, etc.), and maintenance and operation of facilities which are used for the production and distribution of electric power. Unless the economies or advantages, direct and indirect, are sufficient to offset the added costs, (both capital charges and operating expenses), an electrification installation obviously cannot be said to be justified on purely economic grounds. It may be true, to be sure, that the indirect benefits may be of sufficient importance to justify a given project, even though the total actual costs may be increased on account of electrification.

In considering electrification as compared with other possible solutions of any given problems of operation or of traffic, it is not necessarily the *rate* of return on the cash requirements that would control the decision, but rather the actual *total* return. A high rate on a relatively small capital expenditure (of course within reason) might well be less attractive than perhaps a lower rate on a larger investment. For instance, the stockholders of a large company would normally prefer, other things being equal, to spend, let us say, five million dollars to obtain a net return of a million dollars a year (20 %), rather than to spend perhaps a million dollars to secure added net annual return amounting to possibly three hundred thousand dollars (30 %). They are interested in the largest possible increment to their net revenue.

The annual costs of capital consist mainly of interest (or dividends) paid for the money invested (whether the money is borrowed for the installation or whether it is raised by the issue of stock), and depreciation. The interest charges depend upon the condition of the local money market at any given time and upon the credit of the individual railroad, and may thus vary over a relatively wide range. The subject of depreciation is too complicated and controversial for discussion in the present report, but regardless of the details and vagaries of individual accounting systems, it is necessary under sound management to prepare for, and have available a sum of money which will represent, the loss of value which takes place as physical property deteriorates, either on account of wear-and-tear or of obsolescence. If such a depreciation reserve is not set aside periodically from operating revenue, there may be impairment of the capital structure, or it may be necessary to charge to operation at some future time, large amounts for renewals or replacements. The amounts logically chargeable for physical depreciation of capital may vary considerably under different conditions. Radical differences in the predicted life (and indeed the actual life) of the units under consideration may occur among various railroad companies. Some railroads consider that the periodic contribution to the depreciation fund or replacement reserve are subject to credit on account of interest accruals, while some railroads do not allow such credits. These types of difference in accounting policy, together with much other diversity of thought on such questions, result in radical differences in the annual capital charges computed in connection with money required for electrification. It is to be assumed in the present discussion that the annual capital charges for money required for electrification include both interest and depreciation, but it is recognized that such charges may vary greatly among railroads on account of financial conditions and the policy of individual railroad managements.

When requirements for new capital for such facilities as a power plant, or power transmission and distribution systems are to be superimposed upon already existing facilities, the study is relatively simple, but where already existing equipment is to be retired or otherwise modified as to its status, careful analysis is necessary. Railroad electrification involving as it does, a change of motive power, means of course the elimination of steam locomotives in proportion to the extent or scope of the electric operation. Such steam locomotives may be replaced either by electric locomotives, or by motor cars which are often employed, especially in suburban service, instead of locomotives. The value of the displaced equipment, under a sound accounting system, should be charged to « operation » unless the equipment is represented by an accrued replacement reserve fund. The additional capital investment chargeable to electrification is thus the difference between the money required for new facilities, and the value of those which are retired. If the locomotives, for instance, which are to be displaced, represent capital which has been amortized or « written off » through accrual of a replacement reserve fund, and which thus has no value on the books of the company, the equipment which replaces these locomotives may be partially paid for by the replacement reserve or amortization fund which represents the capital value of the old steam locomotives. The revenue from the sale of these steam locomotives or their scrap value may, of course, also appropriately be credited to the cost of new locomotives.

In some instances the steam locomotives or other facilities, which are displaced by the change to electric traction, may be advantageously transferred to other sections of the railroad, or possibly sold for fair prices to other railroads requiring such equipment. It is obvious that the value of the facilities thus disposed of is a credit towards the purchase of the electrification facilities.

It may happen that the steam facilities which are to be replaced, are not written off the books of the company and are not represented by a replacement reserve fund, and that, on account of local limitations, they cannot be advantageously used elsewhere, or sold. Though they may be in physically good condition under these conditions, they are nevertheless of only scrap value. The amortization and interest on any bonds or « equipment, trust » notes (described below), which these facilities represent, must be met just as if steam operation were to be continued. As net savings from electrification would necessarily help meet these interest charges on the old equipment, the value of these locomotives might from some view-points be considered an actual debit against electric operation; that is, it might be held that the advantages or economies of electric operation should be sufficient to pay not only the interest and amortization on the new money required, but on the capital thus displaced. It seems logical however, to correlate the estimated net savings accruing on account of any proposed electric operation, solely with actual new cash required. The economies should, if conditions warrant, be made available for the stockholders regardless of the necessity of payment for equipment displaced, the charges for which must be met whether electrification is decided upon or not.

It is usually possible for a railroad to borrow money under favorable conditions for the purchase of electric locomotives and multiple-unit cars, on what are virtually special mortgage notes known as « equipment trust » notes, secured by the new equipment purchased, to be amortized or paid off from savings currently accruing under operating conditions. This is often a very convenient method of financing the purchase of the rolling stock necessary for the electrification, at a time when capital requirements are necessarily heavy for various other parts of the electrification program.

Taxes are usually considered with the

capital charges. The levying of taxes varies a great deal in various parts of the world. For instance, in some sections of the territory covered in the present report, the railroad taxes are based upon gross revenue, and local taxes are not levied on property used for railroad purposes. In such cases additional facilities would not increase the tax bill and should not be charged against the economies of electrification. On the other hand, when taxes are based upon property values, additional capital would involve added burden, and this should be deducted from the economies estimated. These considerations of course apply only to privately-owned railroads, as government-owned railroads are free of all tax burdens.

Privately-owned railroads in many parts of the world are obliged to pay income taxes, — taxes based upon the net income. It is obvious that savings which may be due to electric operation in-sofar as they increase the net income, would increase the taxes charged against the railroad and these increased taxes are a charge against the electrification which under some circumstances might exert a controling influence against the electrification.

Locomotives.

Electric locomotives possess widely varying characteristics, depending on the design. Some of the characteristics of electric locomotives are more favorable from the standpoint of railroad operating problems than those of steam locomotives, and some are less so. The differences of either nature make difficult, direct comparisons between steam and electric locomotives.

The most common and oldest type of traction motor is the series-commutator type, developed from the earliest days of urban electric operation. This type of motor has a relatively high torque at low speeds, but the torque falls off rapidly as the speed increases. The starting tractive effort of locomotives equipped with series-commutator motors is thus relatively high, a characteristic favorable for starting a train, but as the speed increases, the tractive effort becomes rapidly less. These general characteristics apply whether the power supply for the motor is single-phase alternating, or direct current.

The three-phase induction type motor is also used for electric traction to some extent. If power is supplied from a single-phase distribution circuit, its characteristics are changed to those of three-phase power by means of a phase-converter. The induction motor is essentially a constant-speed device, that is, as soon as it is started, it runs at nearly a constant speed, regardless of the load. In practice there are usually two or more definite running speeds provided by changing the number of poles or by other means. This gives some flexibility of operation since the torque is inversely proportional to the speed. Fundamentally, however, the locomotive equiped with three-phase motors runs at a uniform speed. Thus the demands on the motor, for instance on a steep grade, may be very heavy, whereas on level track it may not be operating at its full rating in view of the fact that its speed cannot be increased. This limits the flexibility not only of the locomotive itself, but of the line, substations and power plant. The advantages of the three-phase induction type of motor are its ruggedness and its simplicity of operation, especially in regeneration of power on descending grades.

The steam locomotive, though it has been very greatly improved in important details in recent years, is in its general arrangement essentially as it was nearly a hundred years ago. Most of the improvements have been in details affecting reliability and efficiency, and many of these improvements have been exceedingly noteworthy. The typical speed-torque or tractive-effort graph of the steam locomotive shows an output as speeds increase which is in general higher than constant horse-power, that is, the maximum horse-power occurs at the higher speeds. This means that the steam locomotive tractive effort at low speeds is relatively less than is the case with series-commutator motor electric locomotives of the same rated capacity, but is relatively greater at higher speeds. This low-speed or starting limitation is often overcome by a « booster », or separate steam engine which may be mechanically connected at starting, usually to one or both trucks of the tender or the trailer truck of the locomotive, and which may be disconnected as the speed is increased.

It is evident from this very brief outline that it is somewhat difficult to compare directly, electric and steam locomotives. The « weight on drivers » which is sometimes used as a method of comparison is not wholly satisfactory, on account of the difference in the shape of the speed-tractive-effort curve, nor obviously is horse-power rating, on account of the widely varying characteristics with varying speeds. It may be said, however, that as closely as comparisons can be made, the electric locomotive under present conditions, costs considerably more than a steam locomotive of the same general power rating. This added cost is a direct debit against electrification, except insofar as it may be offset under certain conditions by greater utilization or annual mileage of the electric as compared with steam motive power.

In comparing the rating or capacity of steam and electric locomotives it should be borne in mind that the steam locomotive must haul fuel and water behind it, and that data regarding drawbar capacity must take this into consideration. The « tender » of the locomotive with its load of fuel and water constitutes often a not inconsiderable part of the total trailing load.

During the past twenty-five years, the efficiency and capacity of steam locomotives has been increased perhaps to a greater extent than for the previous fifty years' period. One of the important results, from the viewpoint of electrification, of the recent improvements in steam locomotive practice arises from the fact that many railroads have recently invested so much money in modern steam equipment that an excessive « writing off » of value would be necessary if this relatively new equipment were to be displaced by electric equipment.

The problem of replacing steam locomotives by multiple-unit passenger coaches may be more complicated than is the problem of merely exchanging electric locomotives for steam, for it is necessary to consider also the passenger coaches which may be retired. Railroads which contemplate sufficiently in advance the possibility of suburban electrification, may so design any passenger coaches which may subsequently be acquired, that they may be readily equipped with electric motors and associated facilities. The change to electric traction when the time comes may thus be economically accomplished, as far as coaches are concerned, without sacrifice of equipment. When figuring the charges against electrification, on account of passenger coaches, and comparing the costs with the value of equipment displaced, any advantages which new equipment may have in comfort, capacity, speed, etc., should, of course, be kept in mind.

Engine house and shop facilities.

A source of expense which may be charged against electrification and which may be of considerable importance, is that for shop facilities for maintaining the electric motive power. It often happens that in spite of the fact that a number of steam locomotives are to be displaced. the locomotive maintenance facilities must be left in commission for use by steam power to be retained in service. If all the steam locomotives are to be displaced, conditions may be such that the character of the shops may not be adapted, without considerable rebuilding, to care for electric equipment. Electric locomotives require other and somewhat different types of tools for their maintenance as compared with steam locomotives. It is very important not to overlook the possible necessity for added shop facilities, or the expense of considerable changes in existing facilities.

Abandoned shops or engine houses, together with coal pockets, water tanks, ash-handling devices, etc. which are not required under electrification and are for that reason retired, are in the same category as displaced locomotives, etc., so far as accounting is concerned. All facilities which are displaced should logically be chargeable to current operation (or against « profit-and loss ») unless they are adequately represented by an accrued replacement reserve fund which may be drawn on for the purpose.

Power transmission and distribution.

The power transmission and distribution system and the substation equipment represent facilities which are entirely superimposed upon the railroad operation and are thus wholly chargeable to the account of the electrification. This applies not only to the capital charges, but to the maintenance and operation, of these portions of the electrification. The charges exist whether or not the railroad owns and operates any or all of these facilities, except that in some instances the transmission facilities and substations may be used jointly with commercial service, in which case the charges may be divided among the various services performed and the financial burdens borne by each service pro rata.

The power distribution system, or « contact construction », is in general necessarily a charge solely against the railroad electrification, as it is not adapted for dual service, except insofar as the supporting structures may also carry transmission circuits for commercial or general purposes. The railroad should usually own, operate and maintain the power distribution system between the substations and the collecting shoes of the locomotives or cars, whether the distribution be by means of overhead trolley wire or by third rail. This is fixed property and is so intimately connected with the railroad operation that responsibility either in ownership or maintenance cannot reasonably be divided. In certain instances as indicated above where all conditions are favorable, the supporting structures may be used jointly for commercial transmission or general supply circuits. In these cases special arrangements may of course be made by the companies affected. Advantage of the distribution construction may also often be taken to support the signal facilities of the railroad including the signals themselves and the signal power supply and secondary circuits. This may produce very considerable economy as a credit toward the expense of electrification.

Included in the cost of distribution of power are such items as inductive coordination with neighboring communication circuits in the case of single-phase systems; or electrolytic coordination with steel structures and with water and gas pipes and power and communication cables installed underground in the case of direct-current systems. These coordination problems involve study with the other organizations involved and carefully planned joint action.

Another necessary coincident problem is the coordination with the railroad signal system, which generally utilizes the running rails as an integral part of its functioning. The railroad communication circuits, which are usually installed along the right-of-way, must sometimes be moved in order to avoid hazard from possible physical contact with the high-voltage circuits connected with the electrification. Sometimes also it is necessary to modify station platform cover-sheds and other structures to provide clearance for pantographs. It may occur that considerable expense in lowering track may be necessary in order to obtain sufficient clearance between the top of rails and overhead bridges or tunnels.

If transmission circuits are installed along the railroad right-of-way in connection with the electrification (where the distribution system is overhead), these circuits are usually supported by the structures which support the contact conductors, and the installation for the transmission thus represents a relatively low increment of investment. The patroling and maintenance of such supply circuits may under some conditions, be more easily accomplished by the use of cars on the railroad, than is normally the case with transmission lines on private right-of-way; though (especially in densely settled territory and constricted right-of-way) location on railroad property may be subject to greater hazard on account of fire on adjacent property or by reason of other abnormal conditions.

It sometimes occurs that high-voltage transmission will make possible an advantageous power contract which would not otherwise be obtainable. The railroad may be able, if it controls transmission facilities, to purchase power at the most favorable possible locations, and transmit it to the points of utilization, regardless of the geographical limits of the electrically-operated zone, or of territory which may be nominally served by any individual power company.

The power distribution system may be defined as the facility for delivering traction power to the moving trains. As has already been said, this must usually be owned, operated and maintained entirely by the railroad, which of necessity must organize forces for the purpose. The requirements of this service vary a great deal among railroads and depend largely upon traffic characteristics. Suburban service, where traffic is very dense and where even a momentary delay may be a serious matter, demands a far more highly organized force than does freight service or service where there may be not more than a few trains a day, and where even a relatively long delay is usually not a great inconvenience. In the former instance there must usually be adequate forces of men continuously on duty within restricted areas ready for service at any time in the event of trouble, while in the latter circumstance, a single small gang which may perhaps be on duty only during its working hours, but subject to emergency call the rest of the time, may well suffice to take care of the maintenance over a large territory. In the former instance the aggregate expense is high and the available working time on the tracks usually relatively low, while in the latter case the reverse is likely to be true. The costs for power-distribution maintenance on two different roads thus may vary so greatly as to be hardly comparable. This item is often one of the largest debits or charges against electrification.

Substations.

The power-distribution system usually includes the protective devices and circuit-breakers which may de-energize circuits under abnormal conditions. It is to be understood that the distribution net-work is usually divided into sections which may be electrically isolated in the event of trouble, or for maintenance purposes. The supply of power for each of these sections is usually controlled by disconnecting switches or circuit-breakers which may be opened manually (or automatically in case of trouble) and closed at will. These switches are in general necessarily an integral part of the power-distribution system. They must, of course, be closely coordinated with the power supply, and are usually the direct responsibility of the railroad's own operators who work in the closest cooperation with the train dispatchers; although if power is purchased, this service may under some circumstances be performed by the power company, especially if the power company operates the railroad substation facilities.

The substation may be owned and operated by the railroad, or by the power company from which power is purchased. If the railroad can advantageously purchase power at the proper feeding-in points, and of the characteristics desired for its power-distribution system, it may do well to save itself the capital expenditure necessary to install its substation facilities, and to employ the power company to perform that function, provided the power company does not value its service in that respect too highly. There is also, under some conditions, advantage to the railroad company in avoiding the necessity of organizing a technical force for operation and maintenance of the substations, a highly specialized duty. This may be accomplished by purchasing power to be delivered at the out-going feeders of the substations. It may be very desirable from some points of view to do this, for the technical problems of substation operation are sometimes not fully appreciated by the railroad management and if adequate support is not accorded to those responsible for proper functioning of the facilities, unsatisfactory conditions may result. The power company, on the other hand, can often more effectively handle the problems through its highly specialized organisation.

The substations may be :

1. entirely automatic,
2. remotely controlled, or
3. locally attended.

The capital investment is relatively the highest in the first instance because of the expensive automatic equipment which is necessary, but, there being no labor for attendance (other than occasional visits for inspection by a maintainer who can thus look after a number of substations), the operating cost is relatively very low. In the second instance an operator is necessarily constantly on duty at some point on the system, but one man on each watch is able to control a large number of substations, and can often perform other duties in addition to that branch of the work. The expense of installation is somewhat less than for automatic equipment, but higher than that for attended substations.

Power generation.

The economy of power plant operation has increased notably during the past twenty-five years. A quarter of a century ago a fuel rate for a steam plant of three pounds per kw.-h. was considered reasonably satisfactory. This represented a thermal efficiency of roughly 8 %, that is, of every hundred pounds of fuel burned, more than ninety pounds were entirely wasted. There are now a number of steam power plants which produce electric energy for about a pound of coal per kw.-h., that is, at about 25 % efficiency, and with such devices as mercury turbines or high pressure steam, the efficiency may be even higher. The fuel cost is perhaps on the order of half the total power cost including capital charges. This is necessarily a very general figure because conditions of generation vary greatly. It is merely presented as an indication that the thermal efficiency is but one of a number of items, and while there may be satisfactory conservation of fuel, as discussed later, this may be offset by other expenses of power generation.

As a general rule, of recent years it has not been necessary for the railroads to build power plants to take care of their traction power requirements. The purchase of power from some readily available commercial system relieves the railroad of considerable capital expenses at a time when there is necessarily a heavy demand for capital for the other items of electrification expenses ; it also relieves the railroad of the necessity for organizing and maintaining a technical department to operate power generating facilities. Even if the power-producing facilities are not owned by the railroad, it is of course necessary for the railroad to pay the fixed or capital charges on the equivalent capital investment for power plant capacity sufficient for the railroad's power requirements. The expenses of maintaining and operating the power plant facilities, labor, material, etc., are also, of course, a charge against the electric traction, whether or not the power plant is owned and operated by the railroad.

The decision between purchase of power and installation of facilities for production, is perhaps the most interesting single problem of all the problems to be decided in any given instance of electrification.

As has been pointed out, in installing facilities for electrification, a railroad is necessarily under a heavy direct capital expense and the more this can be reduced, other things being equal, the better for the railroad. If, therefore, a favorable arrangement can be made with a power company to furnish, at reasonable cost, power of proper characteristics, delivered at the proper points, it is not necessary for the railroad to provide the money necessary for power plant construction, as well as for transmission facilities and even substations ; and if the motive-power may be obtained on an « equipment trust » basis as outlined above, the only actual requirements for capital expenditures which are necessary will be those for the power-distribution or contact system. The railroad, as pointed out above, would necessarily either directly or indirectly pay the fixed or capital charges and costs of operation on all facilities which are necessary for electrification, whether it were to install and own them iself or not. The joint use of power-generating facilities and of transmission lines and substations for combined railroad and commercial functions, under proper conditions, permits advantage to be taken of diversity of load, and thus increases the economy of operation. This, together with certain technical considerations often enables the power company to deliver power to the railroad distribution circuits relatively more economically than the railroad itself could produce its own power requirements.

The rapid growth of a commercial power system, for instance, often enables, with advantage, the continued use of obsolescent generating facilities for carrying peak loads, or for stand-by service, utilising for base loads such new equipment as may be necessary to take care of growing requirements. This new equipment delivering the bulk of the energy output, may embody the most modern development and the highest available efficiency. Isolated railroad power plants, on the other hand, must generally be utilized until the equipment actually wears out, regardless of obsolescence, if full use of the facilities is to be obtained.

In figuring a price for traction power, however, the commercial power company is competing with costs of production by the railroad, and it must be borne in mind that there are several rather important economies of which the railroad may take advantage in producing its own power requirements. The railroad, unless its credit is seriously impaired, may borrow money at a low rate of interest, perhaps considerably less than the dividend rate paid by the power company; this is an important item in computing capital costs which should be considered carefully. Furthermore, in instances where railroad taxes are based upon gross revenue and not on local property value, there would be no direct tax on a railroad power plant as on the plant of a power company. The railroad may compute the haulage of its own fuel over its own system for power generation at an actual out-of-pocket or increment cost which is of course considerably less than the commercial rate. This would give the railroad considerable advantage in cost of coal delivered to the power plant, unless the power company undertakes to agree to receive its fuel over the railroad to which it furnishes power. Under some conditions it is possible that a railroad, on account of large purchases, may be able to purchase fuel at relatively lower prices than can the power company, though obviously this consideration may under other circumstances have the opposite result.

On the other hand, it may be of considerable value to the railroad, as stated above, not to be obliged to organize and maintain technical forces for power plant operation. The chief executives of a steam railroad are essentially not personally interested in the higly specialized subject of power plant engineering, and it is often not possible for them to justify highly technical assistance in the operation of a railroad plant, whereas a large power company, the chief business of which is power production and transmission, can readily justify the employment of a force of technically trained men, each a specialist in his own field, without creating unduly high overhead costs.

In some localities there may exist plentiful and economical supplies of water for power, favorably situated for development for the supply of energy for the electrification of a railroad, but where industrial or commercial demand does not exist. In such cases it might well be the case that it would not be economical, to fully develop the water power except for railroad electrification, and the economy of the development might thus be a controling factor in the decision to electrify. In many localities, however, especially when the commercial or industrial demand is relatively great compared with the hydro-electric power capacity available, the cost of water power approaches, or may even exceed, that of steam power. This is especially true where, on account of seasonal fluctuations in the supply of water, standby steam capacity is required to supplement the hydro-electric power during periods of low water. In such instances the duplicate capital required may offset the fuel savings.

It may be said that in view of the high efficiency of steam plants of the present day, and in view of the relatively high cost of transmission of power, it is not economical to transmit electric power in large blocks, more than a relatively limited distance. Much has been said from time to time about the economy of transmitting large blocks of power from-mouth-of-mine plants many hundreds of miles, to centers of load, rather than transporting the fuel for generating the power. This is practicable to only a limited extent on account of the expenses of constructing and maintaining transmission facilities, and especially on account of the fact that water sufficiently plentiful for condensing purposes is often not available near mines.

Fuel and power.

The use of electric power for traction, of course eliminates, to the extent that electrification is applied, the combustion of fuel in steam locomotives on the road.

Recent improvements in steam locomotive design have in the past twenty-five years more than doubled the mechanical efficiency of steam locomotives, just as the efficiency of power plants has been increased.

Previous to perhaps 1905 it had been an established rule of steam locomotive design that everything connected with the equipment must be as simple as possible, in the interest of reliability and ease of maintenance. The result of such philosophy was that efficiencies on the order of perhaps 3 % were considered satisfactory not very long ago. The development of such devices as radial valve gear, brick arches, superheaters, feedwater heaters, thermic syphons, high boiler pressures, limited cut off, etc. has more than doubled the efficiency and together with the introduction of mechanical stokers, boosters, etc. has very greatly increased the capacity of the steam locomotive. These improvements have permitted very much longer engine runs, with greatly increased loads, and in many instances have modified the method of operation of large sections of railroads in recent years. The continued improvements of steam locomotives have undoubtedty resulted in retarding the adoption of electrification, because among the chief economies of electrification in its earliest days were fuel saving and introduction of long locomotive runs.

An over-all efficiency, under proper handling and with proper load conditions, of 8 % at the drawbar of the steam locomotive tender, perhaps represents normal standard operating practice. From this figure must be deducted the so-called « standby losses ». These losses include the fuel used in starting the fires and waiting for the beginning of the trip, stops at stations, delays at signals, etc., and the heat in the fire and boiler which is lost at the end of the trip or day's work. Obviously these losses may all differ greatly with varying conditions. They are usually lowest for a long locomotive run with no stops, and are greatest for short runs with frequent stops. The maximum locomotive efficiency occurs at some definite and constant speed with a definite load, and the losses are, of course, relatively higher when loads are either heavier or lighter than the normal load. The efficiency is reduced also in accelerating a train or in coasting, also on heavy ascending or descending grades. In addition, there may be leaky valves, stuffing-boxes, etc. or improperly set valves, all of which reduce the efficiency of fuel consumption. Improper handling, such as frequent operation of the safety valve, too late a cut-off, poor firing, etc. may reduce the efficiency very greatly. These limitations may be serious if there is not intelligent and conscientious operation or proper supervision on the road during locomotive runs. These are sometimes difficult to accomplish.

The steam power plant of modern design may generate power, as stated above, at an efficiency of perhaps 25 % at the bus-bar. From this must be deducted for comparison with steam locomotive operation, the losses in transmission, in the substations, and in the distribution system, and in addition the mechanical and electrical losses in the electric locomotives. An overall efficiency of, let us way, 60 % between the bus-bar of the power plant and the drawbar of the locomotive is not far from that reached in practice. This produces a net over-all efficiency figure of perhaps 15 % from coal pile to drawbar. This may be compared with the figure of 8 % given above as the efficiency of the modern steam locomotive operated under satisfactory conditions of speed and load, and without excessive standby losses.

It is less difficult to maintain favorable conditions with electric locomotive operation than with steam motive-power, because adequate supervision over conditions of fuel combustion is relatively difficult with locomotives operating over an extended territory as compared with concentration of supervision possible at a power plant. In addition, relatively more favorable load conditions may usually be maintained with power plant apparatus where there is diversity of load, and where the facilities may be freely placed in service or taken out of service as circumstances require, than with steam locomotives where load conditions are seldom ideal. It may be stated very roughly that under normal circumstances of operation, the fuel saving made possible by electrification may be on the order of between fifty and sixty-five percent. Where short runs and frequent stops are concerned, as in suburban service, and especially in yard switching, this saving may be considerably increased. If water power is available, in whole or in part, the fuel saving is also obviously correspondingly increased.

Fuel saving is also accomplished in electric operation on long descending grades where the electric locomotives are equipped for power regeneration, changing the potential energy to electrical energy. Another source of fuel saving by regeneration would be possible in decelerating or slowing trains by changing the kinetic energy to electrical energy. This is entirely feasible under most conditions, but would mean a considerable added amount of equipment of the locomotive and in general it has not been considered that the economies would outweigh the expense.

The fuel saving due to electric operation, as pointed out above, is of course by no means a net saving, since the capital costs of the power generating and distributing facilities and their operation and maintenance are charges against electrification which tend to offset the saving in fuel, even though from the viewpoint of fuel conservation alone there may be a distinct advantage in electrification. The degree to which fuel saving may be important is measured to some extent by the local cost of fuel. If fuel is expensive, the saving may be very considerable, while if it is cheap, the cost of power delivered at the locomotive may more than offset any saving there may be.

In analyzing energy costs, careful consideration should be given to seasonal variations of demand. This is especially the case where motor car operation is involved. For instance, occasional high demands for heating in winter or on account of some abnormal condition, may reduce the load-factor and increase the cost of power unduly, unless such contingency has been foreseen and provided for, either in the design and operation of the railroad plant if power is produced, or in the arrangements for purchase of power.

In some cases the steam locomotives of a railroad have not been maintained in a modern condition, that is, fuel-saving improvements have not been adopted as they have been developed. In such instances, the analysis of the economies of electrification must necessarily be made not solely with existing motive power, but additional figures should be developed to indicate what economies would accrue if improved steam locomotives were to be acquired. It might well be the case that the maximum *rate* of return would occur with modernized steam locomotives, but that the *total* return from electrification would show a greater aggregate amount even though this might represent a lower percentage on the money invested. If this were to be the case, a decision would be necessary between new steam locomotives (or modernizing the existing equipment) and electrification.

In this connection, a curious argument has been advanced against electrification by a certain class of coal producers who view with concern the reduction in the demand for fuel when railroads electrify. They point out that fuel haulage is a vital part of railroad traffic and that reduction of this, through the use of more efficient combustion methods or by development of water power, would react unfavorably on the railroads. A little thought obviously shows the fallacy of such reasoning. There is seldom any excuse for not taking advantage of the highest available standards of efficiency of operation in any field of endeavor.

Locomotive maintenance.

The application of the various fuel-saving devices to the steam locomotive of today has made it a very much more highly organized machine than it was a quarter of a century ago when the main idea of the designers was to keep everything as simple as possible. This would necessarily be reflected in higher unit maintenance costs, were it not for the fact that it is balanced in turn by the increased use of locomotives, with increasingly heavier trains, and in longer engine runs. The maintenance costs of electric locomotives are somewhat difficult to compare with those of steam, as indicated above, because of the differing power characteristics. It may be said, however, that in a general way there is usually a considerable saving in maintenance of electric locomotives as compared with equivalent steam locomotives. This item is perhaps the most outstanding single general direct operating saving made possible by electrification, though in individual instances, especially in suburban service, there may be other economies of greater importance.

Regarding maintenance of electric equipment of let us say, ten multiple-unit cars as compared with an electric locomotive and ten coaches; it might be expected that the multiple-unit equipment is, other things being equal, perhaps slighly more expensive because a greater number of smaller units make up a given power rating, and furthermore, each car, or pair of cars, is usually equipped with its own protection facilities, power collecting devices, and control facilities, as well as headlights, compressors, etc. Similarly the ten-car multiple-unit train would undoubtedly represent a first cost of slightly more than the electric locomotive with ten standard coaches of similar seating capacity.

The question of the number of cars in the normal train, of course, is of importance in the comparison of costs of this nature. For instance, it is readily seen that an electric locomotive (capable of hauling, let us say, ten cars in local service) used with but perhaps two cars, would be definitely more expensive than two multiple-unit cars without locomotive. The converse is true as above indicated if ten-car trains are considered. As in other questions of comparison, it is impossible to make any satisfactory general statement, but it may perhaps be said that by-and-large the dividing line of equal first cost and of equal maintenance expense would be with normal five or six-car trains. Other considerations such as flexibility of movement, terminal switching, acceleration requirements, schedules, labor costs, etc., would usually control the choice between locomotive operation and that of multiple-unit cars.

Availability of locomotives.

In spite of recent radical improvements in steam locomotives discussed above, there is a considerable difference in the availability for service between steam and electric motive power. This varies with different types of service, and indeed there may be certain classes of service where the limitations of traffic may nearly or quite offset any advantage of electric equipment in this regard. It may be said, however, that electric locomotives are normally available for service a larger percentage of the time than are steam locomotives, not only on an annual basis, including shopping, but on a daily basis, taking into account such operating items as boiler-washing, refueling, cleaning fires, etc. This to some extent, unless conditons of traffic prevent, tends to offset the higher cost of electric equipment.

Train crews.

As stated above, the capacity of steam locomotives has of recent years been steadily increased. In spite of this, however, there are definite limits to the capacity of an individual unit of steam motive power. The width of the firebox and the diameter of the boiler are limited by the track clearances, and the length of the locomotive is limited by various considerations. The aggregate power may be increased by adding separate locomotive units, but this means two additional men in the crew for each locomotive added. Electric locomotives on the other hand, may be readily utilized in any power capacity desired by merely adding units or cabs with multiple-unit control, the practicable limit being the strength of draft gear of the cars to be hauled; no additional personnel is necessary where the units or cabs may be coupled together. This high available capacity of electric locomotives allows the operation of longer trains, especially where grades are heavy, and this often represents a distinct saving in expense.

A further example of crew saving made possible by electrification is in the operation of multiple-unit cars. While two men are required for electric as well as for steam locomotives, in the territory covered in the present report, one man may operate a motor-car train. This may be an important item in considering electrification. There is no fundamental necessity for a second man or helper in an electric locomotive cab, provided various precautions are taken. If in the future it is permitted to operate in that manner, further important economies may be credited to electrification.

Terminal operation.

There are various types of terminals in railroad operation; the three most important are :

1. Locomotive terminals;
2. Passenger terminals and
3. Freight terminals.

These are often closely interrelated from an operating point of view, but may be analyzed separately as regards electrification.

A considerable part of locomotive operating expense is in the terminal, or engine house. When a steam locomotive reaches its terminal, it must undergo a relatively complicated process, for in addition to a general inspection, the ashes are dumped, fuel and water added to the tender and other duties performed, and at certain intervals fires must be drawn and the interior of the boilers washed. All this requires rather extensive facilities and a relatively large personnel at each engine terminal. It is often necessary to locate engine terminals near centers of population on land of considerable value, and a relatively large area is often required for the necessary facilities, which usually include one or more turntables, as well as round-houses, coal pockets, ash-handling facilities, inspection pits, etc. The cost of removing ashes from a large engine terminal in the centre of a city may alone be a major item of operating expense. As compared with all this, the electric engine terminal is a relatively simple affair. No turntable is required for the electric locomotive, which may be operated equally readily in either direction; no coal pockets are necessary, though in some cases fuel-oil and water must be handled in small quantity for passenger-train heating. Inspection pits are generally provided, but no ash-handling facilities are necessary; a much larger share of the terminal labor may be performed within the shelter of the cab of the electric locomotive than is the case with the steam locomotive, with the result that less elaborate shelter is necessary. Many electric locomotive terminals in fact, have no building at all, whereas the « roundhouse » is an integral and essential part of nearly all steam locomotive terminals.

The comparison of steam locomotive operation and maintenance with that of multiple-unit motor cars is somewhat more involved than merely a consideration of replacing steam with electric motive-power units. Many problems encountered with locomotive-hauled equipment disappear when the traction motors are mounted directly upon the cars, and conversely other problems are met in motor-car operation which do not exist with locomotives. Much of the equipment for multiple-unit cars is necessarily mounted under the car body. Pit facilities are thus desirable for inspection and maintenance, and since each motor-car of a long train may require similar attention, it may be necessary to install such pit facilities to take care of entire trains. If each terminal track for multiple-unit cars is not equipped with a pit, a portion at least of the tracks must be so arranged that any maintenance work which may be necessary may be performed. With locomotive operation, the coaches may be left on remote storage tracks for cleaning, etc. and the locomotive moved to a relatively small inspection area. All this means that the terminal maintenance facilities must usually be more extensive for multiple-unit car operation than for electric locomotive operation, though, of course, the actual terminal trackage is no greater, and in fact is usually less than for an equivalent number of coaches plus electric locomotives. Elaborate steam facilities are necessary for heating coaches in winter at the terminals, which are not necessary in the case of multiple-unit cars.

One of the characteristics of multiple-unit car terminal operation is that no switching locomotives are required to make up trains, for obviously the cars supply their own motive power for this purpose. This may be of great value, especially when the terminal tracks are stub-end. It is apparent that when a locomotive brings a train into a stub-end terminal track, it cannot be released for a return trip until the cars can be hauled away. On the other hand, a multiple-unit car train is ready to depart either as a unit, or in part, for a return trip, or a trip to the inspection tracks, as soon as the motorman can walk to the other end of the train. All this, of course, increases flexibility of terminal operation.

The space released by elimination of turntables, coal pockets and ash-handling facilities, etc. may be used for storage tracks which are usually much needed in any busy terminal. Furthermore, if multiple-unit cars are used for suburban traffic, the effective terminal capacity as pointed out above, is increased by the reduced amount of switching necessary. Considering the value of ground area in a busy passenger terminal, the more effectively the property can be used, the better.

Mention should be made here of an arrangement of terminal tracks and operation, possible under special conditions, which simplifies the operation of stub-end terminal tracks under steam operation. In some instances, especially on short runs, trains are operated with steam locomotives on each end of the train, so that no terminal switching is necessary. The expenses of this kind of « shuttle » operation are of course relatively high, since complete duplication of locomotives and crews is necessary. Another type of terminal operation includes so-called « dock tracks », sort track stubs, near the entrance to each individual terminal track, on which switching locomotives may be stationed while waiting for the arrival of a train at the terminal. As soon as the train has reached the platform the waiting locomotive is moved to the terminal track and coupled to the train and is ready to haul the cars to the storage yard; the road locomotive which brought the train into the terminal is thus immediately released, and the track cleared for the next train.

If all service entering a terminal can be electrically operated, the terminal area may be more intensively used by installing two-level operation. While this, of course, does not permit actually doubling the terminal facilities, on account of the necessity of ramp tracks, supporting colums, etc., nevertheless it does allow greatly increased terminal track mileage in a given space. This use of terminal space, provided no steam locomotives are allowed to operate in the terminal, may be made even more intensive by utilizing the « air-rights », the space above the terminal tracks, for revenue-producing buildings.

The economic value of the use of the so-called air rights over the terminal tracks may vary greatly under differing conditions. It may be very high in some localities and may be quite unimportant under other circumstances. In some cities the railroad terminal is close to the center of business and occupies land which has great value. In these cases it would be of great benefit to use the area over the terminal tracks for buildings, because obviously there would be a high demand for hotel or business facilities in buildings which could be physically connected with the passenger terminal. In several instances in the United States, where passenger terminals have been electrified, advantage has been taken of this feature, which has been an important factor in paying the fixed charges on the electric installation.

In many cities on the other hand, the terminals are not located on property which is in demand for hotels or offices, and making available the air rights over the tracks by electrification would not of itself produce adequate return. It is true that the elimination of smoke and noise of steam locomotives might eventually increase the attractiveness and thus by changing the center of business, create a demand for revenue-producing buildings over the tracks, but if the time required to accomplish this were considerable, the delay, unless other advantages were available in the meantime, might well result in a net loss to the railroad. This is especially true where property taxes are levied against the railroad. The increase in property value due to electric operation is under these cicumstances a direct charge against the electrification.

In some cases where electrification of passenger terminals has been accomplished, the controling reasons for changing the standard operation have been mainly other considerations than terminal operation. In these cases, whatever terminal advantages there may be due to electrification are superimposed upon the other advantages or economies.

Freight terminals are not as a rule located where property is of the highest value — even potentially —, though under special conditions there are important exceptions to the rule. In large commercial or industrial centers it has been found desirable to establish warehouse and storage buildings into which railroad tracks are run to platforms for unloading the cars. In such cases a form of motive power other than steam locomotives is obviously desirable. In some instances, where operation into buildings is proposed, internal-combustion engine locomotives may be operated in coordination with steam locomotives. It is however often the case that freight terminal facilities may be advantageously operated as extensions to an existing electrification. Unified operation in any given territory is economical from many viewpoints. This type of problem may sometimes be solved by the use of « three-power » locomotives, that is, electric locomotives equipped also with internal-combustion engines and storage batteries for use on short sections of track which it may not be found practicable to electrify, but normally taking power from the distribution system. The economies in fuel consumption and in maintenance of equipment are high in this type of service, for in yard switching the steam locomotive is operated under more unfavorable conditions than in any other kind of operation. The elimination of smoke and noise may be of importance to the railroad under some conditions from a civic standpoint.

Suburban operation.

This is usually by nature closely allied to passenger terminal operation, for it is often the case that steam railroad suburban service of any magnitude necessarily delivers and takes its passengers at a point not far from an important center of population. The problems of handling suburban service, while they include the terminal, are nevertheless broader, — the terminal problem may be but a minor component part.

The chief advantages accruing from electrifying suburban service, some of which have already been mentioned, may be briefly summarized as follows :

1. Fuel saving;
2. Saving in locomotive crews;
3. Reduction in cost of maintenance of equipment;
4. Accelerated schedules;
5. Smoke abatement;
6. Terminal operation;
7. Added incentive to travel.

Some of these advantages are overlapping and many of them may be said to be general, in that they would apply to any branch of railroad operation. The chief advantages of electrification often appear in suburban service.

Against the advantages, however, there are disadvantages mainly due to relatively high capital investment with low factor-of-use or load-factor, on account of the so-called « fleet movement » of trains into the city in the morning and away at night, which creates high peak demands, with little demand during other hours. The high capital expenditures are thus divided by relatively small traffic mileage, and it is obvious that, once the installation is made, operating economies are in general proportional to the traffic mileage. This low load-factor of suburban service, of course, applies not only to the power supply, but also to the cars, track, signals, power distribution system, in fact to all departments of the railroad operation.

A number of problems in electric operation of suburban service may be brought about by dual steam and electric operation in the same territory, which is the case if the electric equipment handles only the suburban service, and steam locomotives handle « through » passenger and freight traffic in the electric zone. This kind of operation necessitates duplicate engine terminal facilities, and thus practically double costs on that large item of operating expenses. The smoke from steam locomotives in electrified territory is very deteriorating to whatever overhead electric contact system there may be, and results in unduly high maintenance expenses for such facilities. These evils are in some instances mitigated by electrifying the « through » passenger and the freight service in the electrified zone, and thus eliminating the steam locomotive entirely, at the same time filling the valleys or low points between peaks in the load curve, and thus increasing the factor-of-use of the electric power generating and distributing facilities. There is still involved in such cases, however, a duplicate locomotive terminal at the limit of the suburban territory, and the necessity of stopping « through » trains for change of motive power, with consequent delay and expense. The necessary double locomotive terminal means also not only high expense of operation, but very often, in addition, the electric locomotive investment is superimposed upon the capital represented by the steam locomotives, with little opportunity to release steam equipment in spite of the reduced steam locomotive miles. This duplication also applies to some extent to the locomotive crews.

In some cases suburban territory includes a nomber of branch lines forming a sort of network. While the service into the terminal may be exceedingly heavy under these conditions, it may happen that the service over any individual branch may be very light, that is, the factor-of-use of any individual mile of track may be low. This means that the high capital expense of a large mileage of power distribution facilities may perhaps be divided by relatively few car-miles per year, and since the savings are in general dependent on the car-miles operated, the result may be that the economies will not pay the fixed charges. A railroad suburban zone with a multiplicity of branches is, other things being equal, less attractive from the standpoint of electrification than is a territory where the traffic is operated over a single route.

There is throughout the territory included in this report, more mileage of what may be called suburban electrification than of any other kind of electric operation. In a considerable proportion of the installations of this type, « through » passenger traffic within the electrified zone is operated by electric locomotives. In the other instances, electric operation is confined largely to the suburban passenger service (see appendix).

The fuel saving in suburban service is usually relatively more important than in other kinds of service (except in yard switching), for the frequent stops and acceleration of trains in local service results, as has been pointed out above, in relatively unfavorable loading conditions on steam locomotives, and thus low operating efficiency. Furthermore, as has already been said, the standby losses in steam locomotives in suburban service are relatively high on account of station stops and the short distance between terminals, resulting in short locomotive runs. The electric motive power is not subject to these limitations.

In analyzing costs of power and comparing with steam locomotive fuel costs, consideration must be given to the fact that with more rapid acceleration and higher speeds which usually accompany electrification, the power consumption is necessarily greater than it would be at the old rate of acceleration and speed. Direct comparison should obviously correlate the power costs as of the same schedules, and the increased power consumption due to better service should be so charged.

It has already been pointed out that the saving in locomotive crews through the use of motor-cars is on the order of one-half, since the normal practice in steam locomotive operation requires two men per locomotive, whereas but one man is required at the front end of the motor car train. This is one of the most important economies in suburban electrification. A not unimportant corolary of this feature is the economical operation of more frequent service, especially in short trains outside of rush hours, which is made possible by the reduction of train crew personnel.

A further advantage of off-peak operation of short trains lies in the fact that off-peak electric energy is relatively cheap, as it is not subject to demand charges. The fuel cost with the steam locomotive is the same regardless of the time of day. In this connection it may be logically pointed out that the energy consumed in the operation of a motor-car train is roughly proportional to the number of cars operated in the train, while with locomotive-hauled trains, the weight of locomotive and tender being constant regardless of the length of the train, becomes relatively a more important item of expense, the shorter the train.

The motor-car train allows a very ready and convenient means of substantially increasing scheduled speeds in suburban service where stops are frequent. The application of power throughout the length of the train makes possible an acceleration rate which it would be difficult to obtain with a long train drawn by a locomotive. Wherever suburban service has been electrified, schedules have been accelerated, with consequent attraction of additional traffic. This has also allowed a substantial increase in track capacity, especially during rush hours, when trains are operated on close headway.

The smoke abatement due to electrified suburban service tends to attract passengers, not only on account of the increased luxury of riding in itself, but on account of the fact that property along the electrified zone becomes more desirable and is thus chosen more generally for residential purposes. Each added residence in suburban territory not only increases passenger service demands, but also freight traffic on account of commodities, such as fuel, building material, food, etc. required by the occupants.

A minor but not unimportant item in suburban electric operation is in flexibility of switching cars. This has been mentioned in connection with terminal operation, but in addition it has in some cases been found economical in electrified suburban territory where branch service is a consideration, to cut in two outward bound trains of motor cars, sending some of the cars on the branches while the main portion of the train proceeds along the main line. The process is reversed in incoming trains. The same kind of operation is applicable to mixed local and express service, — a portion of the train may be dropped off at a station, proceeding as a « local » after the rest of the train has proceeded as an « express ». This method of operation economically provides added service which would be expensive under conditions of steam operation. Increased service usually results in increased traffic.

It often happens that it is practicable to accomplish joint or coordinated operation between electrified suburban operation and local rapid transit facilities, perhaps running the suburban trains over the tracks of the rapid transit company, often in a subway for local distribution of passengers. This kind of coordination is of course not practicable unless the standards of clearance and characteristics of electric power distribution and current collection, etc., are the same for the electrified railroad and local rapid transit organization.

Tunnel operation.

A long railroad tunnel, especially where there are heavy grades, may constitute a serious problem under steam locomotive operation, on account of smoke and gases. This results in inconvenience to passengers and train crews, and may involve delay to service. Such long tunnels usually require more or less elaborate ventilating systems, and even with these, there may be conditions of service or weather which may make operation difficult. In some instances, even under favorable conditions, such tunnels with steam operation may constitute a limitation to the traffic capacity of the railroad and become

« bottle necks ». In these cases the alternatives usually lie in construction of a second tunnel bore, for additional tracks, or electrification of existing tracks. Of these alternatives, electrification of the tunnel in spite of its drawbacks, may be found to be the more economical.

The drawbacks of electrification under these circumstances lie mainly in superimposing the expense of electric locomotives on that of steam locomotive operation, and sometimes also in the interrupting of advantageous steam locomotive runs, and in the duplication of engine terminal facilities and of locomotive crew expenses; in fact, the entire electric operation costs in tunnel electrification are in general practically superimposed upon those of steam operation. In spite of the drawbacks, however, this kind of operation has been found justified in a number of instances in the territory covered in the present report, not only in the case of isolated tunnels but in one or two cases in tunnels operated in connection with terminal operation. In some instances, electrification which was installed primarily on account of isolated tunnel operation, has been subsequently extended to include a natural operating district, advantage being taken in these instances of other economies accruing from electric traction, especially in the operation over long heavy grades, both ascending and descending and in handling dense traffic, etc.

Mountain grades.

In hauling heavy trains up long grades, the steam locomotive in spite of recent improvements, is at a disadvantage, both as regards efficiency and capacity. It is often necessary to operate steam locomotives under these conditions, two or three, or even more, to a train, to secure the necessary capacity. With electric locomotives, on the other hand, as has been already pointed out, capacity to any reasonable extent can be obtained by increasing the component units of the electric locomotive, all the units being under the ready control of a single individual. The economy on this account may amount to a very considerable item.

The advantages in such electric operation furthermore are not all indicated on *ascending* grades. One of the difficult problems of railroad operation is the handling of heavy trains on long *descending* grades. Electric traction motors can be arranged if desired, to act as generators to convert the mechanical energy of the moving train to electric energy, just as they convert electric energy to mechanical energy in hauling the train. The electric energy thus generated on down grades may be fed back into the power distribution system to serve as useful power to assist in moving other trains, or for commercial purposes; or it may be absorbed on the locomotive itself in the form of heat. In the first instance, to feed power back into the line, the necessary equipment on the locomotive is somewhat more complicated than in the second, where electric braking only is accomplished, but the conservation of the power is of course an advantage as compared with its waste or dissipation as heat.. Several railroads in the territory covered in the present report, which operate in mountainous districts, have taken advantage of the various general economies, as well as the special advantages which electrification provides under these conditions (see appendix). In most of the instances regeneration is accomplished on descending grades. It is of interest that the railroads which feed power thus regenerated back into the transmission system are in many cases so situated that the economic value of the energy thus saved is relatively small, for in most of the instances the power is originally generated either at hydro-electric plants or in steam power plants which are situated near coal mines where the fuel cost, and thus the actual economic value of the salvaged energy as such, is relatively low. The chief value in electric braking is holding the trains on the grade and thus reducing wear-and-tear on the equipment and increasing the comfort and safety of operation. The maintenance of brake-shoes is a large item of cost in operation on long descending grades.

Smoke abatement.

The steam locomotive burning soft coal, even with careful operation, necessarily produces smoke on occasions, and this is especially troublesome in populous localities, although various investigations in different parts of the world have indicated that in urban districts the smoke produced by steam locomotives, even in busy railroad centers, is but a small part (on the order of about 6 %) of the total smoke in the air which the people breath. The smoke emitted from locomotives, however, is released at such low altitudes that it is more obvious than that from tall chimmeys, and is thus more subject to comment. It is of course true that there is a possibility that this characteristic of steam locomotives may be overcome in the future, but little progress in this regard has been made up to the present time.

There are of course instances where the reduction of smoke may be of economic benefit to the railroads as well as of civic advantage to the community. Reference has been made to situations of this sort in suburban service and in terminal and tunnel operation. There may be advantages in reducing smoke in order to attract traffic to the railroad, especially where there is a tendency for traffic to be diverted to some other form of transportation. As has been pointed out, electrification of suburban traffic for instance, may create a tendency towards building up the suburban territory served by the railroad on account of increasing the comfort of travel, and on account of the added attractiveness of property along the railroad for residential purposes. The increased values at terminals made possible by reduction of smoke, has also been referred to. The absence of smoke from steam locomotives may also attract (especially in summer) travelers who would otherwise use their own automobiles or patronize highway coaches. It has been the experience of a number of roads that the electrification of suburban service has definitely caused increased traffic, and some of this increase has undoubtedly been due to the increased cleanliness of travel. It is true that in some instances suburban commuter traffic (especially from points relativeliy close to the urban terminals which can often be more economically handled by local rapid transmit facilities) does not produce adequate financial return to the railroad handling it. Nevertheless, it is important that having undertaken the responsibility for handling this class of traffic, railroads make as economical use of the facilities as possible. Furthermore, the advantages of cleanliness and better service may be translated into higher fares from the commuters, to thus reimburse the railroad for value received.

There is a tendency in some instances on the part of public authorities to require railroads to electrify in order to reduce smoke. Irresponsible action of this kind which may force railroads to spend large sums of money without adequate return, is highly pernicious, and will inevitably result in retarding the normal economic development of electric traction, and will thus be of great harm in the long run, not only to the railroads, but to the people whom they serve. If the railroads are to be asked to refrain from emitting smoke, other industries should, of course, be included, and the public which expects to benefit should participate in the costs.

Increased speed.

The steam locomotive of present standard design has reciprocating parts, and this means necessarily unbalanced dynamic mechanical forces. These unbalanced forces become of increasing importance as the speed increases, and at high speeds they may be very considerable, and provision is necessary to insure that they do not adversely affect either the machine itself or the track and bridges over which it runs. In the case of the electric locomotive on the other hand, the moving parts are usually all strictly rotating so there is no necessity for any unbalanced dynamic forces at any speed. This means that the electric locomotive is relatively more favorable mechanically at high speeds than the steam locomotive. Under conditions where there is a tendency for traffic to be diverted from the railroads in favor of other means of travel, it may well be found desirable to increase schedule speeds, and in such event serious consideration may be given to the replacing of the steam locomotive by the electric locomotive for long « through » runs. It is true that steam locomotives are in service, which were designed to be run at very high speeds, and do successfully operate at such speeds, — nevertheless the mechanical stresses under these conditions are high and this means careful and costly maintenance of the machines themselves and of the track over which they operate.

The increased schedule speed made practicable by multiple-unit cars on account of rapid acceleration has already been mentioned in connection with suburban service. Notable acceleration of schedules has usually been made with the inauguration of electrification on various suburban projects and this has undoubtedly added to the traffic demands.

Miscellaneous.

The unbalanced dynamic force of steam locomotives traveling at high speeds has been mentionned. These unbalanced forces exert pressure on rails and bridges often far greater than the mere weight of the locomotive itself. This necessitates heavier bridges for a given weight of equipment than with electric locomotives where all important moving parts are purely rotating. It sometimes occurs that the cost of rebuilding or reinforcing bridges for increasing weights and speeds of steam locomotives, may be saved by the introduction of electric motive power. The ability to increase the concentration of tractive power by adding units or cabs of electric locomotives, that is, by virtually lengthening the weel base of the locomotives, also acts to the advantage of electrification in this respect, in a manner which may under some conditions be of great importance. In the same way, electrification may under some circumstances make unnecessary a program of rebuilding turntables and roundhouses to take care of increasing over-all lengths of steam locomotives and their tenders.

A number of other considerations, the evaluation of which is difficult, are made available by electrification. The absence of cinders dropped on the track ballast by steam locomotives reduces the necessity for cleaning the ballast as often as is otherwise necessary. Bridges over the tracks do not require painting as often with electric operation as with steam, though it is true that this advantage is somewhat offset by the fact that where there is overhead contact construction, the cost of painting overhead bridges may be slightly increased. The danger of setting fires, especially in woodland or prairie districts due to hot sparks from the stacks of steam locomotives is of course eliminated with electric operation. The visibility of the track ahead and of signals, is usually considerably more favorable from the cab of the electric locomotive or multiple-unit car, than from the steam locomotive, though this advantage may be somewhat discounted where cab signals are employed.

One of the difficult railroad operating problems in some sections is the supply of proper feed-water for steam locomotives. It is often expensive and sometimes nearly impossible to obtain economically and treat adequately such supply in outlying districts. This problem is not present with electric operation. One of the important incidental advantages of electric operation is the availability of electric power along the right-of-way in electrified territory for miscellaneous purposes, such as station lighting, shop power, power for track tools, etc. Feeders of proper characteristics may be readily supported upon the facilities provided for the support of the power distribution system and arranged for tapping at convenient points. Such power, without electrification, would usually not be economically available in rural districts through which the railroad operates; and even in suburban or urban territory may be usually more economically furnished from the traction system than in any other way.

One advantage which may be seriously taken into consideration if railroads are government-owned, or subsidized by the State, is the saving of time of passengers in transit. Such savings, amounting to even a few minutes per day, multiplied by passengers carried per year, represent a total aggregate which is startling. Privately owned railroads, of course, cannot logically capitalize such advantage unless they can be translated into increased fares, but with publicly-owned railroads the case is different. Government-owned railroads may also of course include in the contemplated economies of electrification, the appreciation of land and property values along the right-of-way, which may under some conditions amount to very large figures, and in such cases would produce direct returns in the form of higher taxes. Privately-owned companies of course cannot do this, and increased assessed values on property used for railroad purposes, as pointed out above, may be an actual debit against electrification. In this connection, mention has also been made of the possibility of serious increase of taxes when a direct property tax is levied upon a railroad, and of reduction in the savings from electrification on account of income-tax levies which are charged against net income.

Conclusion.

An attempt has been made to discuss briefly the expenses due to electrification, and to analyze the sources of economy or indirect advantages made possible as an offset to the heavy capital and operating expenditures involved in the installation, and to indicate in a very general way to what extent, in the various countries, covered in the report, these considerations have operated (see appendix). It is impossible to present specific comparative figures of steam and electric operation which would be of general value, and no attempt has been made to do so. Data received in reply to questionnaires issued by the Association and from other sources are widely divergent and indicate that conditions vary exceedingly, not only geographically, but chronologically. Each individual example of any proposed electrification must thus be analyzed with great care, with consideration of local conditions of such items as fuel, labor, finance, power supply, etc. Density of traffic, which is a measure of factor-of-use of the facilities employed in electric traction, is, other things being equal, a measure of the direct return from any electrification project. Obviously the more intensive the use of a given facility, the greater the return on its cost.

Improvements are constantly being made in steam and internal combustion locomotive design and construction as well as in electrification standards. It is a temptation of conservative railroad managements to await ultimate developments before deciding upon policy. Such philosophy is not readily defensible and if widely adopted would result in serious stagnation of progress.

Each of the heavy electrification projects already installed is satisfactorily functioning and has without doubt fulfilled the economic and operating requirements under which it was installed. While many of these existing electrifications were originally started as solutions for some local problem, a number of these have been extended in scope and territory to take advantage of general broad economies, and it is probable that the installation of electric traction projects will show increasing growth as time goes on.

II. — SELECTION OF SITES FOR GENERATING STATIONS.

There are perhaps three main types of electric generating stations — hydro, steam and internal combustion engine. The selection of sites is of course affected by many considerations, only a few of which can be briefly analyzed in the present report. No attempt is made to analyze economies of production as among the various types of plant.

In selecting the location of a power plant, consideration should be given to the kind of load which is contemplated. If a base load is to be carried and the facilities are thus operated at high load-factor, a more elaborate design of all parts of the installation for maximum economy is justified than in cases where high peak loads are to be carried, and a relatively small amount of energy output is required, or where the facilities are to be used mainly as standby for other plants. It may be said as a general thing that the higher the factor-of-use of any facility, the more capital can be advantageously expended upon that facility, other things being equal.

The same philosophy applies to locations of plants relatively to their load. If a base load is to be carried, the plant may economically be located relatively further from the center of the load than when this is not the case, since the higher the factor-of-use or load-factor of the transmission line, the more energy will be transmitted relative to its capacity. Conversely it is obvious that if a plant is to serve mainly as a standby plant and where the operating costs will thus be a relatively smaller part of the total costs, the location with respect to the load should be chosen largely with the idea of convenience and reliability (the transmission distance being as short as practicable) rather than with the idea of maximum economy of operation.

An important consideration in selecting the location of any power plant is the accessibility for operators and materials. The hauling of heavy machinery which is utilized in power plant installation is a very serious question unless adequate and economical means for handling such weights are provided. This applies not only to the original installation but to the subsequent problems of maintenance. Railroad connection into the plant for handling heavy materials is exceedingly convenient and may be a controling factor in the choice of location. Rail connection is usually installed if possible, wherever coal is used as fuel, and this may be used of course for other material. If rail connection is not available and delivery by water is practicable, heavy materials may often be economically handled by this means into the plant. Road facilities are obviously an alternative to either rail or water transport, but the transportation of heavy materials by road may be very expensive and routine hauling of fuel by that means may add very heavily to the cost of power production. If oil or gas is burned as fuel, the supply connection by means of pipe lines may be very satisfactory but this does not solve the problem of transportation of heavy material, such as transformers or parts of generators and turbines or structural steel.

In connection with the accessibility of the plant location, it is of importance to consider the personnel which will operate the plant. Since operation of a plant is normally on a twenty-four-hour basis, two or three shifts or watches are usually employed for each operating duty, and a considerable number of employes thus must reach and leave the plant every day. If there is not a community nearby where these employes may live comfortably, and travel conveniently to and from their work, it is often necessary for the management to provide housing facilities of its own, because satisfactory service will not be received unless living conditions are attractive enough to induce the right kind of people to accept employment. If the plant is not accessible to an established community, it may indeed be necessary for the management not only to construct dwelling houses but to provide retail shops or stores, schools, churches, places of amusement, etc. This item is common to all types of power plants, though the number of people involved is smaller in the case of hydro-electric plants than with other kinds.

Among other considerations of importance in the selection of a site for a steam power plant is the question of possible criticism from the neighbors due to smoke, cinders and noise, especially in urban or suburban territory. The item of noise also applies to the internal-combustion-engine plant. The facilities for storage on the premises of fuel, whether coal, oil or gas, the actual or potential value of the land occupied, and the opportunity for expansion with the growth of load, are also important items. Not the least of the considerations is the provision for the power output, that is, the electric transmission and distribution facilities. If the power is to be used for railroad electrification, and the plant is located adjacent to the railroad right-of-way, this is not usually a serious problem, unless the right-of-way is too narrow or otherwise restricted to be of service, but if railroad property is not available, the physical requirements of the transmission line may be a controling factor in affecting the location of the plant. High-voltage transmission of power requires a considerable space unless cables are employed, and cables for the higher voltages are expensive.

Space is an important consideration in selecting the site for any power plant. Inadequate space for the necessary facilities usually results in high operating costs and reduced reliability, for it means a constant compromise between ideal design (which includes the proper relative location of the facilities with regard to each other), and the room available. This applies not only to the original installation but to arrangements for subsequent growth or expansion. The land chosen for the site, therefore, should not be so expensive as to make the cost of adequate space too great. Plant facilities are increasingly being designed for out-of-door installation, to avoid the necessity for expensive buildings. This includes all departments of the plant, boilers, turbines, busses, circuit breakers, etc. Such outdoor installations should be allowed to spread over as large an area as necessary to permit the most favorable possible design.

Hydro power plants.

Hydro-electric plants may perform the following functions or a combination of functions depending upon the relation of such items as original cost of installation, continuity or reliability of water supply, local costs of fuel, and available steam facilities :

1. Base load with steam plant connection for peak load;
2. Average load;

3. Peak load or emergency loads or voltage regulation, with steam plants for base load;

4. To make up deficit of water for feeding other hydro-electric plants.

It is obvious that a hydro-electric plant must be located in the vicinity of a fall of water; there is thus usually not much choice as to the general location. The amount of power available in a fall of water is measured by the product of the height of fall and the quantity of water falling. The supply of water should be reasonably constant, either by nature or by constructing storage facilities which will conserve the supply in times of plenty for use in times of drought. Full information as to water available should be determined in advance by extensive preliminary surveys of the water-shed and collection of flow data over a period of years. The fluctuation in the supply of water may be seasonal or there may occur every few years, a year or two of dry weather which will seriously affect the flow. In either case, a standby supply of some kind is usually necessary, which may take over the load in dry times. This standby may be in the form of steam plant or internal-combustion-engine, or distant hydro-electric capacity, or it may be in the form of a large reservoir which is kept full at all times to be drawn upon in such emergencies.

In developing a hydro-electric plant site, a dam is usually necessary. This should obviously be located at a point where its construction will be as inexpensive as possible, everything considered. A foundation at bed rock is usually necessary and the nearer this bed rock is to the surface, the more economical is the dam construction. Before final decision on the site is reached, deep test drillings should be made to explore the sub-strata, in order to so design the dam that there will not be ultimate slippage or settlement due to clay, shale, underground streams or voids.

The power plant is not necessarily located at the dam site, though obviously the nearer the dam it is, the shorter will be the head-water installation and thus, other things being equal, the simpler and cheaper the construction. If often occurs that the best site for the power plant will be relatively far down stream from the dam, or even in another valley, if full advantage is to be obtained of the total maximum possible drop or fall of water. The connection from the head-waters to the plant may be in the form of an open canal, a tunnel, a pipe or a combination of each. In some instances a siphon over an intervening elevation may be found economical. Local conditions must determine the arrangement in all cases.

A question sometimes arises as to the relative expense and advantage of installing an number of small plants along a stream as compared with a single high dam which would enable utilization of the entire drop at one location. Obviously a single plant would have advantages in operating economies and in installation cost, unless the amount and character of the area flooded and the expense of the high dam is sufficient to offset the advantages accruing from consolidation of the facilities. The cost of dam construction increases rapidly with increased heights.

It is of importance to design and locate hydro stations so that they will not be adversely affected by flood conditions. It goes without saying that the utmost precaution should be taken to avoid danger of physical damage from floods, but in addition it sometimes occurs that unless the tail waters are adequately disposed of at times of flood, the loss of head at such times results in seriously impairing the output of the plant, and the abundance of water is under these circumstances a drawback.

Adequate provision should also be made to prevent trouble due to ice. This may be among the serious operating problems of hydro-electric plants and should be kept in mind in the location, design and construction of the facilities.

The development of automatic operation has enlarged the economic scope of small hydro-electric plants where the output would not be sufficient to justify constant attendance. There are many such plants in operation, which function automatically, connecting themselves to the power system when water conditions and load conditions justify, and cutting themselves off when water is low or the load has dropped to a predetermined amount.

A somewhat special phase of location of hydro-electric plants exists where some elevated artificial storage may be made available to absorb power when water is over-plentiful, by pumping the surplus water into the storage reservoir, to be utilized at times of drought. Such a device may be designed to take care of seasonal variation or even daily conditions when the fluctuations are severe; the power plant being used at night or at periods of low demand, to pump water into storage for use during the day. It may even be possible if all conditions are favorable, to develop a system to utilize water power which may be superabundant in one locality as supply to another locality which may be temporarily lacking in water, in pumping water back into the reservoir at night, or during other off-peak hours, to be used during the hours of demand.

Another application of this general principle is in instances when *capacity* is relatively expensive compared with *energy*. It is sometimes justifiable to pump water for storage by steam power even at a considerable loss of energy, in order to increase the available capacity.

In some instances, natural storage reservoirs have been installed near the head-waters or streams to retain the flow during the natural period of plenty, usually in the spring, and feed it out to plants located along the stream as required. Such regulation has worked very satisfactorily especially where the drainage-area of the stream is relatively small, and where the stream thus is subject to sudden and severe fluctuations in flow. In such instances it is usually found desirable to locate a plant at the point where the stream flow is to be controled, in order to utilize the water as it is started down the stream from the storage reservoir.

In some cases the storage reservoir is installed by the government primarily for flood control. In such instances the power requirements are necessarily secondary, but the use of such energy as may be available may be an economic advantage, especially where provision can be made by interconnection of power systems for utilizing the power thus produced to supplement other sources.

A coordination which may under some conditions be of considerable importance is that between hydro-electric generating facilities and navigation. It sometimes occurs that a dam or series of dams equipped with locks may be constructed which will impound water of sufficient depth to allow navigation on a stream or lake which would otherwise not be navigable. In such cases the joint use of the water for power and commerce may justify the expenditure of very considerable sums of money for construction which would not otherwise be economic. Either the power or commerce might be considered a by-product of the other. A number of such instances are in operation and others are projected throughout the territory covered in the present report.

A similar coordination scheme may be applied if conditions are favorable as between hydro-electric power development and water supply for municipal purposes. If surplus head is available in the city water supply, it is logical to employ this energy usefully before delivering the water to the city supply mains. Such coordination may result in material economy.

Steam power plants.

Steam plants may perform any function from base load to peak or standby service. The design and location are of course intimately associated with the service they are installed to perform.

The location of steam power plants is a far more flexible matter than that of hydro-electric plants. Three fundamental considerations must be met at any site selected :

1. Condensing-water, free from corrosive contamination due to manufacturing refuse or other cause, and in sufficient quantities to insure at all times a low enough temperature to obtain satisfactory vacuum in the condensers;

2. Feed-water of proper characteristics for the boilers, and

3. Supply of fuel and its economical delivery at the power plant.

Three different types of fuel are usually contemplated in connection with steam plants, unless special conditions make other kinds locally economical (such as refuse of various kinds which would otherwise be of no value). The three fuels usually of importance are : 1. coal, 2. oil, and 3. natural gas.

Coal is under present conditions the most generally used of all fuels, on account of the fact that its presence is most widespread. Oil is found in abundance in many localities and is next in importance. Natural gas is growing in importance rapidly, as means for transportation at high pressure by pipe lines are being developed. Coal is usually transported either by rail or by a combination of rail and boat. Few coal mines are located on tide-water or navigable bodies of water or streams, and nearly all the coal mined thus starts its journey by rail. Experiments have indicated the possibility of transporting pulverized coal, suspended in water, in pipe lines, settling and drying the coal at the point of delivery. This however is not yet of a great economic importance.

Coal-burning plants located on navigable water are usually equipped to take fuel from either railroad cars or boats, thereby obtaining the benefits of flexibility of transportation, both as regards rates and reliability. On this account, and considering the supply of condensing water, locations on large lakes or rivers and on tidewater are attractive as sites for steam plants.

Oil may be transported by rail, water or through pipes, and the considerations mentioned above also apply to some extent to oil-burning plants as they do to coal-burning plants; in fact, in a number of cases plants have been equipped for burning oil, coal or even gas in the same boilers, changing readily to the type of fuel which happens to be cheapest at any given time.

Natural gas is very abundant in some parts of the world, and provides an ideal fuel for steam power plants. Its use is extending rapidly with the development of high-pressure pipe transmission and storage, and it is possible it will be generally used in place of oil or coal in the not distant future. Plants equipped for burning natural gas or oil may be located at any convenient point where there is ample condensing-water and good feed-water, regardless of rail or water transport facilities, since merely a pipe connection is all that is required for the supply of fuel.

A number of special conditions may determine the location of a steam plant; among these may be mentioned the use of waste heat in blast furnace areas. This kind of arrangement makes possible the manufacture of power virtually as a by-product, and limitations in efficiency might therefore be tolerable which would not be considered in a plant constructed solely for the production of electric power. These considerations apply also to some extent in connection with large gas plants and to other industries where coal in large quantities is used and where other demands for steam are considerable. Mixed-pressure turbines have greatly facilitated joint operation of this kind.

From many viewpoints it is logical to contemplate locating power plants as near as possible to the source of fuel supply and instead of transporting the fuel by rail, water, or pipe, to transmit the energy in the form of electric power after it is generated. This is especially the case when it is possible to reclaim mine refuse (either anthracite or waste from coal-cleaning processes), which may have long been accumulating, and which it is not economic to transport long distances on account of high noncombustible content. This may be economical under some circumstances, though it is generally true that there is not a satisfactory supply of condensing-water, and sometimes even of feed-water, in the vicinity of coal mines. Furthermore, long distance transmission of power in large blocks is not accomplished without considerable cost, in both capital and operation, and these costs must be recognized in any analysis of expenses. The question resolves itself in the last analysis to one of the relative expense of transportation of energy in such material form as fuel, as compared to transportation in the form of electric power.

Internal-combustion-engine power plants.

Internal-combustion-engine power plants are very flexible in their operation and of high thermal efficiency, but the cost of installation is high and the size of individual units relatively small. This type of plant is sometimes used to carry peaks or as standby on account of its flexibility of operation, and sometimes used for base load for small systems on account of its high efficiency.

The considerations for internal combustion plant locations are much the same as those for the location of steam plants, except that the problem of boiler-feed-water of proper quality and of condensing-water of proper quantity does not apply. A relatively small supply of cooling water with a cooling tower if necessary, is usually adequate. The question of noise may be of importance in some neighborhoods, though proper precautions are usually adequate to prevent complaints on this account. The supply of fuel is usually in liquid form, and thus may be delivered by pipe-line, but the problems of handling heavy construction parts usually make a rail connection desirable. Internal-combustion engines are available only in units of relatively limited capacities, and this obviously affects the economical size of the plant which in turn affects its location. Internal-combustion engines may be favorably operated under some conditions in conjunction with certain manufacturing processes which produce as by-products, gases of a combustible nature. In these cases they are of course located close to the industries with which they are associated, and the power output fed into the general power system.

Conclusion.

A large number of considerations, of course, govern the choice of sites for power plants and an attempt has been made here to discuss briefly only a few of the more important items. It is obvious that in the space available, an incomplete review only is possible. It is the thought that this brief analysis may provide a vehicle for free discussion, which it is hoped will be forthcoming, and that the discussion will provide data of value to the membership of the International Railway Congress Association.

III. — CHOICE OF KIND OF CURRENT IN RAILROAD ELECTRIFICATION.

One of the most widely-discussed questions in connection with railroad electrification is the question of the choice of the kind of current, that is, the « system » of electrification to be used. The term « system » used in this connection, generally refers to the system of power distribution, for it is on that basis that the power is delivered from the substations to the moving locomotives or cars. Any one or more of a number of forms of electric power may be delivered as convenient to the substations, and various types of traction motors and associated apparatus may be used on the electric rolling stock, receiving power from the distribution circuit; but once the characteristics of the distribution system are determined, only those types of electric locomotives or cars which are adapted for using that particular form of power or « system », may be utilized to collect the power and to operate over the tracks so equipped. Interchange over these tracks with motive power of other standards is usually difficult or impossible.

In the design of any railway electrification project, there are five major divisions :

1. Power supply;
2. Power transmission;
3. Substations;
4. Power distribution;
5. Motive power (locomotives and motor cars).

The choice of the system of electrification depends not only upon the adaptability of each of these five divisions or departments to perform most effectively the service required of it, but upon the inter-relation of all, and the economy and effectiveness of the installation as a whole.

A number of different systems of power distribution have been developed during the past thirty-five years since the inception of what may be termed heavy electric traction. This was natural, as there were no data available as to relative costs, and important developments were constantly being accomplished in each system, throughout most of this period. While it was natural, and perhaps necessary, that this diversity of development should have occurred, it has in many respects been most unfortunate, for it has meant the unduly heavy expense of manufacture of apparatus which accompanies non-standardized designs and production, and it has meant also a serious limitation of interchange of electrical equipment, and of joint track operation among neighboring railroads. The growing diversity of systems has also operated to retard or postpone certain electrification projects which would have been economically more than justified, because of the disagreement among engineers as to the best method of electrification. There are now available sufficient data to permit full engineering agreement, and it is to be expected that the present decade will see complete standardization in any given territory, of all fundamental matters connected with railroad electrification.

Among various systems of railway electrification which have been developed, each individual installation was originally designed to meet some local problem, and there is no doubt that all of these projects have functioned as they were intended to function, and performed successfully the operations they were designed to perform. The various systems thus operating may be divided into two major parts :

1. Alternating current, and
2. Direct current.

Each of these may be in turn divided into several groups.

Direct-current power distribution systems are now operated at any one of a number of nominal voltages. These voltages as operated in the territory covered in the present report, may be roughly designated as 600, 800, 1 200, 1 500, 2 400, and 3 000 volts. There is of course some actual variation from the nominal voltage zone in individual instances.

Alternating-current power distribution may be subdivided fundamentally between three-phase and single-phase, and each of these subdivisions may again be divided not only on the basis of voltage, as with direct-current, but also on the basis of frequency. Commercial frequencies have now been reduced to generally accepted standards of twenty-five cycles, fifty cycles and sixty cycles per second in the territory covered by this report. The two latter frequencies are too high for satisfactory use in alternating-current railroad power distribution, and the frequency which has been standardized for this purpose in the territory covered in the present report, is 25 cycles per second, though in other parts of the world lower frequencies are used. The frequency of 25 cycles was originally adopted as being the lowest frequency which could be used for incandescent lamp illumination, and it was the thought that as a compromise this frequency might be practicable for universal adoption. With the modern incandescent electric lamp, however, there is a noticeable flicker with 25 cycles, which has made the use of that frequency undesirable for general use, and while the 25-cycle frequency has persisted in certain localities, it is now used for general commercial purposes in only a limited and gradually diminishing territory.

The lower the frequency, the more favorable is the design and construction of certain types of motors, and the more stable is the transmission of large blocks of power over long distances. On the other hand, the cost of transformers rises with the lower frequencies and while electric lamps may be tolerated under some circumstances at 25 cycles, any lower frequency is entirely out of the question for general lighting purposes. This, of course, reduces the flexibility of use of lower frequencies.

It is of advantage when two systems of different frequencies must be operated in conjunction with each other to choose the frequencies so that there is a simple relation between them. Thus 16 2/3 cycles is used with 50 cycles on account of the simple ratio of 1 to 3. The ratio of 25 to 60 cycles (5 to 12) as used in the United States also allows a fairly simple pole arrangement when synchronous frequency - changers are used.

Although there is apparently more choice of detail among alternating-current systems than among direct-current systems, nevertheless actually there has been more complete standardization of alternating-current, where it has been adopted, in the territory covered in the present report. In the districts included there are no three-phase systems of power distribution now in operation, all the alternating-current installations, except two, being operated with single-phase power distribution on the basis of nominal characteristics of 11 000 volts, 25 cycles per second. The only single-phase electrifications not on this voltage are a short tunnel electrification which utilizes 25 cycles at 3 300 volts on the trolley and a suburban installation where 25-cycle, 6 600-volt distribution is employed.

The systems of electrification, or power distribution systems which are considered in the present report, are therefore :

1. Direct-current at nominal voltage zones of 600, 800, 1 200, 1 500, 2 400 and 3 000 volts, and

2. Single-phase at a frequency of nominally 25 cycles per second and at no-

minal voltages of 3 300, 6 600 and 11 000 volts. The data in the appendix indicate the relative mileage of track electrified with these various systems of power distribution and the characteristics of power distribution of a number of typical examples of electrification in the territory covered in the present report.

Power supply.

It would be quite ideal if power for railroad traction purposes could be of such characteristics that direct connection could be made from commercial circuits. This is, however, not practicable, as outlined above, because commercial power is now usually generated and utilized three-phase, alternating-current at either fifty or sixty cycles per second and these characteristics are not satisfactory for use in railroad traction circuits. If commercial power is to be used for electric traction, the power characteristics must therefore be changed either to direct-current or to alternating-current of lower frequency.

The question immediately arises as to whether it is desirable to furnish the traction power from commercial power systems, or to construct power plants and transmission facilities for the especial purpose of supply of power for traction loads. The answer to this question depends upon local conditions.

Regardless of the system of power distribution and of other technical considerations, it must be borne in mind that any railroad load is subject to relatively heavy and sudden power demands or load swings, caused by starting heavy trains. If the commercial system which may be available for furnishing power is relatively small compared with the demands for electric traction, these sudden heavy swings may adversely affect the other users who jointly receive power from the system. The power-consuming public, except in certain rural territories, now properly demands and expects relatively more accurate regulation of voltage and frequency than is necessary for heavy-traction circuits and if sudden increases or decreases of load in large amounts are not to be felt as fluctuations of voltage or frequency on the associated commercial circuits, relatively large capital investments may be necessary.

Traction power is necessarily collected from bare conductors by means of moving contacts on trains traveling often at high speeds; furthermore, the distribution circuits installed along the tracks, accessible as they must be to the power-collecting devices, are subjet to accidental contact or malicious interference. This means that accidental grounds or short-circuits may be relatively frequent compared with such troubles on purely commercial circuits, and if these abnormal conditions are not to be felt by other commercial users, relatively large investments for protective apparatus again are necessary.

On the other hand, if the railroad traction load is not large compared with the commercial system which is available to supply it, the swings or abnormal conditions (provided proper protective devices are installed) are not of great moment, and the railroad power supply may be taken from an available commercial system without undue capital investment. There may be, moreover, the advantage that as often happens, the demands of the traction load do not occur at the same time as those for commercial power; that is, there is some diversity-factor which tends to increase the economy of use of the equipment.

The development of power plant economies during the past few years has been contemporaneous with an increase in the size of all the fundamental units of power plant facilities. For instance, turbo-generator units of the order of twenty times as large as the largest units of twenty-five years ago are now not uncommon. The boiler-room equipment unit has similarly grown in size out of all proportion to that in service only a relatively few years ago. The increasingly large sizes of individual units of power-plant apparatus possess the limitation that the total plant capacity must be large if the standby capacity is not to be relatively excessive in cost. If, for instance, a two hundred thousand-kilowatt turbo-generator unit is out of commission for inspection or repairs, two hundred thousand kilowatts of generator capacity, which would normally be idle, must be called into service. Such large standby or reserve capacity is now usually taken care of in commercial power systems by utilizing obsolescent facilities, not economical for normal or base load operation, but perfectly satisfactory for occasional use, and also by interconnecting with other neighboring power systems, so that each system supplies a certain amount of reserve capacity for the others. This is perhaps the chief benefit accruing from the interconnection of power systems, which isolated systems do not have.

In considering the power supply for traction purposes and in making a choice between purchasing commercial power and constructing its own power plant, a railroad management must take into account the fact that with a relatively restricted load like that involved in the supply of a single isolated railroad electrification, large generating units are not practicable, and that small power plants are in general fundamentally not as economical as large central stations.

A large number of considerations of course enter the analysis of power supply and space does not permit full discussion. It may be said, however, that by-and-large, unless some special local conditions govern, the decision as to the supply of power is not dependent upon the systen of power distribution chosen nor conversely is the choice of the power distribution system dependent upon whatever power supply may be most economically available, since the power generally cannot be used in the distribution system in the form in which it is generated.

An exception should perhaps be made to the general statement which has just been made, in recognition of the case of a power plant which might for one reason or another be built especially to supply the power for railroad traction, or a large part of the output of which might be used for traction, and which might necessarily be isolated so far as interconnection with other plants is concerned. If the system of power distribution which is chosen, is in the form of single-phase, 25-cycle, and it is found desirable to construct such a power plant especially for the railroad load, a decision is necessary between generating the power in the form of single-phase at low frequency, or in generating it at commercial frequency, three-phase and converting it either at the plant itself or at outlying substations to single-phase power at traction frequency, the frequency-changing equipment used in such cases being in a general way somewhat analogous to the rectifying equipment necessary for direct-current railroad distribution systems.

If single-phase power distribution is to be used, it is of course relatively simplest to generate and distribute the power directly at single-phase of the traction frequency, stepping up the voltage if necessary for transmission. There are, however, limitations to this method of handling the problem. A generator designed for single-phase load is usually, though not always, wound for a three-phase output but there are certain modifications necessary as compared with a standard three-phase machine, such as special field windings, additional mechanical bracing of coils, etc. A three-phase machine designed for single-phase output is necessarily operated at considerably lower rating than a machine of the same general size generating balanced three-phase power where all the windings are equally and fully utilized. It is sometimes the case that a generator, whether driven by a turbine or a motor, which is designed for single-phase load is wound for a single-phase output only. If this design is adopted, there is considerable saving in the size and weight of the unit, as compared with a three-phase machine.

It happens in some of the localities covered in this report as mentioned above, that the standard three-phase commercial system is a twenty-five cycle system. In such instances it may be physically possible to tap the single-phase load from the three-phase circuit, but this has the disadvantage that any considerable load unbalance of this kind among phases means that the modifications in the design of the generators, and a material reduction of rating as referred to above, must be adopted, and also that the voltage of the commercial output will be somewhat unbalanced among the three-phases, which may affect the capacity of three-phase facilities commercially supplied from the plant. It may be said in general that not more than about 10 % of the total three-phase load may be thus taken as single-phase output without difficulties. It is not practicable as a rule to attempt to equalize the railroad load geographically among the phases on account of the necessity of continuous contact on the distribution system. The installation of phase-balancer devices to equalize the single-phase load among the three phases has been used to offset these limitations up to the extent of the capacity of such a machine.

In general it has been found desirable to segregate the single-phase from the three-phase load, even when the frequency is nominally the same. This is accomplished either by the use of frequency-changers or by separate turbo-generators supplied from the power station steam mains and operated by the power station crew. Frequency-changers of various types have been developed; the most common design consists of two synchronous - synchronous units mounted on the same shaft. If however, the frequencies of either power system thus connected are subject to variation, a variable-ratio type of frequency-changer may be used, the load transferred being under control of the operator regardless of relative frequency in the two power systems.

Transmission.

The problem of power transmission is closely associated with that of generation, since the characteristics of the generated power usually determine the characteristics of the transmission. If three-phase power is generated at a standard commercial frequency of 50 or 60 cycles per second, the transmission line may be of this characteristic at a voltage at which transmission is most economical, taking into consideration the distance and amount of power involved, or if single-phase distribution is adopted, the transmission may be either three-phase or single-phase as seems more desirable under the load conditions. Three-phase high-voltage transmission, utilizing three conductors per circuit, is somewhat more economical of copper than a single-phase circuit, consisting of two wires, carrying the same amount of power. The frequency does not materially affect the actual efficiency of transmission, though from some viewpoints the lower the frequency, the more readily solved are some of the transmission problems, such as inductive effects, stability of long lines, etc. Porcelain insulators at high voltages are an important item of expense, and even though a few more units per string may be required for a single-phase circuit than for a three-phase circuit of equal nominal voltage, fewer strings obviously are necessary and this would indicate an advantage in favor of the two-conductor, single-phase, circuit as against a three-conductor, three-phase, circuit.

As regards the physical or mechanical design of transmission lines, it is obvious that, other things being equal, a two-wire circuit is somewhat simpler to install and maintain than a three-wire circuit. The towers or supports, which are necessarily designed for maximum ice and wind loading imposed on the conductors, are less heavily loaded, other things always being equal, by a two-wire circuit than by a three-wire, even though the individual wires of the two-conductor lines may be somewhat larger. A relatively small difference in imposed stresses, applied as they necessarily are at a considerable distance above the ground, may mean an important difference in the weight and cost of the supporting structures and their foundations.

Transformers designed for lower frequencies are necessarily larger and more expensive than for the higher frequencies. There is considerable economy of transformer costs as well as costs of protective apparatus, especially where large blocks of power and high voltages are concerned, in concentrating the main transformer capacity at a relatively few substation locations as compared with spreading it about at a relatively large number of points, as discussed below.

It is impossible to state definitely without complete analysis of an individual installation, that three-phase transmission at high voltage and commercial frequency is more or less expensive than single-phase transmission of an equal block of power, at traction frequency. It may be said, however, that when it is possible to correlate the railroad transmission with that of a commercial system, the burdens of capital and operation may be shared, thereby perhaps relieving the railroad electrification of a considerable part of the expense of transmission. Such coordination of transmission facilities is not usually practicable with single-phase transmission at traction frequency, and unless there are other controlling factors, the choice of three-phase transmission at commercial frequency is indicated if coordination or joint use of transmission facilities is to be obtained. In this connection, however, it should be noted that it is usually economical to receive power, either by purchase or production, from a minimum number of different sources if the maximum benefits of diversity of load and of quantity-purchase, are to be obtained. It may therefore be economical to disregard the possible economies of joint power transmission if by so doing there may be concentration of supply.

Substations.

The question of substations is vital in considering the choice of a system of power distribution. The power supply and high-voltage transmission may both be independent of the distribution system, but the design and location of the substations obviously depends entirely upon the kind of distribution system chosen.

The general location and spacing of the substations, all conditions of traffic, track arrangement, etc. being equal, obviously depends fundamentally upon the distribution voltage, whether alternating-current or direct-current is employed. Losses in distributing power are in general inversely proportional to the square of the voltage; reducing a given voltage by half for instance, would multiply the distribution losses by four, and conversely, doubling the voltage allows four times the length of circuit with the same amount of copper and assumed loss of power. This means that with any given loss which may be considered reasonable or economic in the distribution of power, the higher the chosen distribution voltage the further apart the substations may be placed, and conversely that the closer the spacing, other things always being equal, the less the line loss. Electrolytic and inductive coordination problems however, and some other considerations, it should be noted, are simplified by close substation spacing.

The consideration of spare capacity of substation apparatus is an important item. One spare unit or machine for each substation is conservative policy, though the spare capacity may be distributed to some extent among neighboring substations if conditions warrant. It is apparent that, other things being equal, the smaller the individual units of substation apparatus the less spare capacity relatively will be required.

In general, the greater the spacing of substations the greater the economy of both construction and operation. The more closely spaced the substations are, it may be said in general, the lower relatively will be the factor-of-use or load-factor of each individual substation, all other things being equal, and the greater therefore the total aggregate installed substation capacity must be, although it is true that the aggregate substation capacity is not affected by spacing the substations further apart than the normal train spacing. Other things being equal, the larger the individual substations, the greater the economy per kilowatt of installed capacity, and the less the unit expense of maintenance and operation if manual, though if the substation equipment is automatic, or remotely controlled, the cost of operation is little affected by the substation spacing. As discussed elsewhere in the present report, substations may be operated manually or by remote control, or they may be automatic, placing themselves in or out of service as load conditions demand. The economies secured by automatic equipment may under some circumstances justify closer spacing due to a reduction in the amount of copper used for feeders, etc.

It is thus apparent that the distribution voltage and thus the substation secondary or output voltage, which is chosen, should be as high as is consistent with other considerations, regardless of whether the system of distribution is to be direct-current or alternating-current. The choice of voltage is of course dependent upon a number of considerations, such as kind of traffic, density of traffic, number of tracks, length or route, etc. When the voltage has been decided upon, the substation locations may be chosen and their general design developed.

It is usually convenient to place the substations near junction points and « interlocking » stations where there are crossovers between tracks, because at such locations the contact conductors (whether a.c. or d.c.) may be advantageously sectionalized and thus isolated by means of circuit breakers or switches, under the control of the substation operator, in the event of grounds or short circuits or for purposes of maintenance. Such an arrangement allows trains to cross over at either end of a section and thus pass around a section of the line which may be temporarily out of service.

In designing the substations, the fundamental consideration is the choice between alternating-current and direct-current output to the distribution system. Although many considerations, as implied above, govern this decision, one of the most important of these lies in the characteristics, and hence the cost of the substations.

Alternating-current substations. — The substations are simplest if single-phase distribution with single-phase transmission is adopted, because with such an arrangement the substation will consist merely of static transformers and necessary switching or circuit-breaker facilities. As with substations of other types, the switching operation may readily be accomplished by means of remote control from a central point, so attendance is not required. Since all the important facilities are static, the maintenance is relatively simple; practically all apparatus is out-of-doors, so very little shelter is required.

As stated above, in the cases where alternating-current is employed in the territory covered in the present report, the distribution voltage has been standardized at nominally about 11 000 volts. The use of this relatively high voltage usually permits the economical location of the substations at any point which may be convenient from an operating viewpoint. The spacing is dependent upon such local considerations as density of traffic, plan of the zone electrified, inductive coordination, etc.

If the power supply is at commercial frequency of 50 cycles or 60 cycles, and the distribution is at a lower frequency, at least one of the railroad substations must contain frequency-changer apparatus. This at present is necessarily rotating apparatus and thus requires an installation somewhat more elaborate than that for transformers only.

If frequency-changing is accomplished at a substation, it may be generally economical to adopt an output voltage such that the supporting structures for the railroad circuits may also carry transmission circuits of proper characteristics for the supply of power over a relatively large territory. In these instances there may be necessary but one or perhaps two frequency-changer substations for the entire electrified zone, depending upon its extent and upon traffic requirements, the remaining substations consisting merely of static transformer and circuit-breaker facilities as outlined above. Frequency-changers of the general type under discussion may be readily built in any capacity desired.

In designing a substation for frequency-changer facilities, practically all the apparatus may be arranged for outdoor service, including transformers, circuit breakers, bus structures, and the frequency-changer sets themselves. Whatever instruments and other auxiliary facilities it may be necessary to protect from the weather, may be installed in a small, inexpensive building or within the foundations of the main machines themselves. If necessary, an overhead outdoor crane may be furnished for handling heavy parts during installation and for maintenance, but even this is not necessary where railroad facilities are available, for with proper substation arrangement, the railroad wrecking crane facilities may be economically utilized to serve this purpose.

Direct-current substations. — If direct-current is chosen for power distribution, the substations usually perform the function of changing the power characteristics from three-phase alternating current to direct current of the distribution voltage chosen. This as stated above, may be nominally 600, 800, 1 200, 1 500, 2 400 or 3 000 volts in the territory covered in the present report. The considerations as already stated, apply in general to the voltage of distribution whether it is alternating or direct current. As pointed out above, it is advantageous, other things being equal, to choose a voltage as high as possible, of course recognizing other limitations, and to space the substations as far apart as possible consistent with keeping down the losses in the power distribution to an economical figure. The spacing is dependent upon such local considerations as density of traffic, plan of zone electrified, electrolytic coordination, etc.

Direct-current distribution at nominally five or six hundred volts was adopted in the earliest railway electrification projects, and has been highly developed for rapid transit lines and for steam railway electrifications, which have some of the characteristics of rapid transit lines, i. e. relatively short route mileage and very dense passenger traffic. In such installations, even though the substations are necessarily spaced relatively close together and a great deal of copper is required for distribution, the load characteristics may result in a factor-of-use or load-factor of the individual substations which is not unduly low. If, however, the electrified territory is extensive, and if demands for power are mainly concentrated in perhaps a relatively few individually heavy trains, either passenger or freight, the economies of the low voltage may quickly disappear, and higher distribution voltages are indicated. The multiplicity of voltages which have been adopted in the territory covered in the present report, is an indication of the careful choice of the specific voltage which is best adapted in individual problems for each contemplated service.

The synchronous rotary-converter was early developed to effect conversion of power from alternating to direct current. This was originally designed largely for twenty-five cycle, three-phase input, because some added stability was possible at that time with low frequency, but as commercial power has gradually been standardized at higher frequencies, the design of the rotary converter has been improved and at present, synchronous-converters may be designed satisfactorily for operation at any commercial frequency.

The practicable output voltage limits of a synchronous-converter may be said to be approximately 1 500 volts. If the voltage for the power distribution is chosen at higher than 1 500 volts, the operation of single-armature synchronous converters is not very satisfactory and two machines may be operated in series. If rotary conversion apparatus is to be used at these higher voltages, motor-generator facilities are usually indicated. Where motor-generators are utilized for high-voltage direct current, a three-phase synchronous motor is often mounted upon a single shaft between two direct-current generators which are connected in series, so that the voltage generated by each is one-half the voltage of the distribution line to ground. Such an arrangement is very satisfactory and presents the advantage of reducing commutator ripples, and maintains high power-factor in the transmission circuits. The arrangement also tends to reduce possible troubles due to surges or short-circuits on the distribution system. This type of machines has been widely and successfully used for direct-current voltages up to 3 000 volts in the territory covered in the present report.

Many recent electrifications which utilize direct-current distribution have successfully adopted static rectifiers of the mercury-arc type, rather than rotary machinery for conversion of the power supply to direct current. They occupy considerably less room than rotary apparatus of the same capacity, and this is, of course, economical when building expenses are considered and where cost of land is high. It may indeed be predicted that before long, mercury-arc rectifiers will operate as outdoor apparatus just as transformers are now operated, a small shelter being provided to protect the vacuum pumps, metering instruments, relays, and other auxiliary apparatus. Rectifiers of this type also lend themselves very favorably to installation as portable substations, where flexibility of location is desired.

Rectifiers have been successfully installed for all distribution voltages up to 3 000 volts in the territory covered in the present report, and in capacities up to 3 000 kw. per unit. It is probable that larger sizes will be utilized in the not distant future. This type of apparatus is operable from three-phase primary supply circuits of any voltage and frequency, the associated transformers of appropriate design furnishing power of proper characteristics for the rectifiers themselves. Since the rectifier is primarily merely a « check valve » which allows the supply current to flow in one direction but not in the other, the internal losses are in the form of a definite drop in voltage which is independent of the voltage of the output. This means that at higher operating voltages, the losses are proportionately less than at lower voltages, that is, the efficiency of the apparatus increases with the operating voltage. Furthermore, the efficiency is nearly the same over a wide range of loads. There is not a great deal to choose between the efficiency of a static rectifier and that of a rotary converter at the 600-volt range, though at low loads the rectifier efficiency is somewhat more favorable than that of the converters, and this results in a more favorable all-day efficiency. At higher voltages the rectifier has very considerable advantages as regards efficiency. The same is true of installation costs, for at higher voltages the rectifier is considerably less expensive per unit of capacity than rotating apparatus of similar capacity, or indeed than rectifiers of similar capacity at lower voltages. It may perhaps be said that rotating direct-current conversion apparatus is now virtually obsolete except in instances where it may be desired to regenerate and feed power back from the locomotives (on descending grades or in decelerating the train) into the distribution system and through the substations into the transmission system.

Summary. — Either alternating-current or direct-current systems of distribution may be supplied from mainly outdoor substations if desired. Commercial power supply for high-voltage alternating-current distribution may be concentrated at one substation or at two or more widely spaced substations if desired, utilizing rotating frequency-changers of the capacity required, delivering power at any chosen voltage and stepping up the voltage for transmission along the railroad right-of-way for step-down at transformer substations along the route, if desired. If direct-current distribution of power is adopted, the substations, other things always being equal, are usually spaced more closely together than with alternating-current distribution on account of the relatively lower voltage utilized up to the present time for direct-current distribution. This characteristic may be of importance under certain local conditions, and may be of no importance whatever under other circumstances.

The power transmission circuits may be installed along the right-of-way of the railroad (or across country if the railroad route is tortuous), feeding the substations in turn, or the power may be supplied to the railroad substations from neighboring commercial transmission networks, and changed at the substations to the characteristics desired for distribution. It may be said that any substation whether alternating-current or direct-current may be operated manually or may be automatically or remotely controlled, as desired.

Distribution system.

As stated above, it is the distribution system only which determines the designation of the « system » of electrification in any given case. The power distribution circuits function to convey the power from the substations to the moving trains which collect the power by means of contact devices. The distribution system thus includes the contact system, which may be in the form of a third rail or an overhead contact wire. The distribution systems now in operation in the territory covered in the present report, as explained above, are of alternating current at 3 300, 6 600 or 11 000 volts, or direct current at 600, 800, 1 200, 1 500, 2 400 and 3 000 volts. Whether the system is alternating current at either of the voltages mentioned or direct current at voltages above perhaps 1 500 volts, it must usually be carried in conductors over the tracks, for there is a hazard if higher voltages in bare conductors are installed near the ground, even though the conductors may be protected by trunking or other means. This indicates that for practically all modern railroad electrification, except that where the characteristics are those of urban rapid-transit facilities, the power distribution is by means of an overhead contact wire. When high speeds are involved, the overhead contact wire is usually supported at frequent interval from a messenger strand or cable so that it will not sag greatly between supporting hangers. This type of support is usually known as a « catenary » system which is a term very widely used in railroad electrification. The catenary system derives its name from the messenger strand which supports the contact wire and which hangs in a curve approximating more or less closely a catenary curve. The mechanical requirements, whether alternating-current or direct-current distribution is employed, are that the contact wire will lie smoothly over the track without sudden rises or drops relative to the running rails, so that the collecting device on the moving train, usually a pantograph shoe held up against the wire by springs or by compressed air, will follow the wire at all times, and will not bounce off and thus draw an arc.

The measure of electric power as commercially used, is roughly the product of volts times amperes (disregarding a number of technical qualifications), and it is thus apparent that the lower the voltage for a given amount of power, the greater must be the amount of current collected at the pantographs. With lower voltages, more copper or copper equivalent is necessary in the contact or catenary system for a given amount of power, regardless of whether alternating-current or direct-current distribution is employed. The more copper required, the heavier the supports necessary to hold it in its proper location with necessary factors of safety; furthermore, the greater the amount of current which must be collected by the moving contact on the train, the more contact area is necessary, other things of course always being equal. This contact area may be increased either through the design of the contact system or of the pantograph or collecting shoe, or both, but it is desirable, especially when high speeds are involved, to keep the weight of the pantograph shoes at a minimum to reduce as much as possible the inertia in a vertical plane.

The distribution system usually includes auxiliary feeders of one kind or another, carried upon the structures which support the catenary system. These auxiliary feeders may be positive feeders in parallel with the contact system, or they may be negative feeders designed to supplement the track rail in carrying the return current back to the substation, or both. If alternating current is used, the auxiliary feeders may be high-voltage circuits which carry the single-phase transmission to the outlying substations along the route, or they may be balancing conductors installed to reduce inductive effects on neighboring communication circuits. Whatever the designed function of the auxiliary feeders is, they are usually conveniently carried on the structures which also support the catenary or contact system. As with the contact members and transmission facilities, the capacity of the auxiliary conductors is dependent on the voltage. The higher the voltage, the smaller and lighter they may be for a given amount of loss of power transmitted.

The problem of insulation is an important one; indeed there is perhaps no single item in the distribution system which is more important. The failure of one insulator unit out of perhaps many thousands, may tie up an important section of the railroad, and cause serious delay. The insulation requirements, of course vary with the voltage; an 11 000-volt circuit, for instance, requires more insulation than a 1 200-volt circuit. The insulator problem is aggravated somewhat by the fact that in most electrified territory there is also some steam locomotive operation, and smoke and cinders from steam locomotives are thus often discharged at high velocity immediately under the insulators, covering them with moisture, soot, and acids. The fact that the distribution circuits operate with rail of ground return also affects the duty under which the insulators operate. Much more elaborate insulation is therefore necessary along railroads than with commercial power transmission lines of the same nominal voltages. The cost of insulation is a charge against higher distribution voltages which must be offset by advantages if the higher voltages are to be justified.

The problem of electrolysis in direct-current distribution, and of electro-static and magnetic induction in alternating-current distribution are of importance and should be carefully analyzed in planning an electrification and making a choice as to the characteristics of distribution power to be adopted. Since practically all systems utilize the running rails as return to the substations, and since the insulation of the running rails from the ground is necessarily very slight, there is considerable tendency for leakage of this return current from the rails into the ground. If this stray current is direct current and if there are parallelling water pipes, gas pipes, electric power or communication cables or steel structures in the neighborhood, careful and constant effort is necessary to insure that these foreign facilities are not adversely affected by the stray current. On the other hand, if alternating-current distribution is used, there may be inductive interference with neighboring parallel communication circuits belonging either to another company or to the railroad itself. Joint studies and coordinated measures are necessary to prevent undue troubles from this source. There may be inductive disturbances from direct-current circuits and there may be electrolytic difficulties from stray alternating-current circuits, but in general these problems are both of little importance.

Reference has been briefly made to three-phase heavy-traction power distribution. There is at the present time no instance of this type of distribution in the territory covered by this report, the one installation which was originally made (in the United States) having been subsequently modified to single-phase. In the three-phase system of distribution two contact wires over each track are necessary, each insulated for full voltage from the other and from the rails, the rails being the third conductor of the three-phase circuit. The collector on the locomotive is divided electrically into two parts, each insulated from the other. This arrangement is obviously relatively complicated both to install and maintain. For instance, at turnouts, crossovers, etc., the two conductors of different phases must cross each other mechanically, retaining smooth contact for the pantograph shoes, and being completely insulated from each other electrically. It is largely for such reasons as this that this system has not been more widely used in the territory covered in the present report.

Summary. — The lower the distribution voltage the heavier and more expensive usually will be the distribution system (including auxiliary feeders) and supporting structures, other things being equal, though insulation is more expensive at higher voltages. Electrolysis and inductive coordination are problems which must be considered in direct-current and alternating-current electrification respectively.

Motive power.

The electric locomotive and motor-car designs are among the fundamental considerations in the choice of a system of power distribution. The traction motor and its control present special problems in design which are met in no other service. The characteristics of various types of traction motors have been referred to in another portion of the present report. Briefly stated, the following types of traction motors are principally used :

1. Series-commutator motor for direct-current;
2. Series-commutator motor (with modifications) for single-phase alternating-current, and
3. Induction three-phase motor.

If direct-current distribution is chosen, the first type of motor mentioned is universally used, while all three types may take power from single-phase alternating-current contact wire, provided appropriate apparatus is interposed. Locomotives are now operating successfully from single-phase distribution systems in the territory covered in the present report, with each of the three types of motor mentioned.

The series-commutator direct-current motor is the oldest type in traction service and in some respects the most satisfactory in its characteristics. It has relatively high starting torque or pull, which is of course readily translated into high starting tractive effort, and it is rugged in its construction. The torque falls off relatively rapidly as the speed of the motor increases, and at the higher speeds the horse-power output is thus relatively low. The disadvantage of this type of motor, unless it is supplied from a motor-generator on the locomotive equipped with field control, lies in the necessity for external resistance in starting. The voltage of the direct-current distribution system is practically immutable once it has been selected. The voltage across the terminals of motors which are supplied from the distribution circuit is thus also immutable, and must be so controlled that it will not at any time be unduly high. When such motors are first connected to the supply circuit, at starting, outside resistance in the circuit is necessary to prevent damage. The use of this resistance, especially where stops and starts are frequent as in local suburban service, is wasteful. When the motor has been brought up to speed, the starting resistance is no longer necessary, and where long runs and infrequent stops are involved, the starting losses are not relatively very important. The amount of resistance necessary in the control of motors of this type is reduced to a minimum by connecting the traction motors, or groups of them first in series at starting, and as the speed increases changing the connection to series-parallel or full-parallel. Flexibility is further increased in some instances by weakening the motor fields in the last position of the controller to obtain increased speed.

The design of the single-phase series-commutator alternating-current motor is more favorable, the lower the frequency. The twenty-five cycle motor of this type is very like the direct-current series motor in its operating characteristics but is somewhat more expensive to construct as it has some complications which the direct-current motor does not have, though especially in recent designs, there is little essential difference in characteristics. It is usually necessary to ventilate this type of motor from an outside source, whereas the direct-current motor is often self ventilated. The chief advantage of this type of motor is in the flexibility of control of the supply voltage, and the ability, by means of transformer taps, to maintain horse-power output over a wide speed range with varying distribution system voltage. It is also adapted for operation from direct-current supply circuits of proper characteristics or single-phase supply alternatively.

All locomotives and multiple-unit cars which use alternating-current single-phase motors are necessarily operated through transformers which change the high trolley voltage to low potentials for use in the traction motors. The starting of the alternating-current series-motor is accomplished by using transformer taps, beginning at low voltage and stepping up the voltage ratio as the motor gathers speed. In this way power is not wasted in heating grid resistance as is the case in starting direct-current motors from the supply circuit. The transformer taps may be conveniently chosen for both starting and running with maximum consideration for the most effective motor characteristics.

When direct-current traction motors are operated from a single-phase distribution system, there is interposed a motor-generator set mounted in the cab of the locomotive, taking single-phase and delivering direct-current power. In these cases the generator output voltage, and therefore the traction motor supply voltage, may be varied by means of adjusting the field of the generator. The motor control is thus accomplished without the use of outside resistance in the main circuit as is the case when the supply voltage is inflexible. This makes possible a very flexible and satisfactory method of control, but of course involves the added expense of the motor-generator set.

The chief characteristic of the three-phase induction motor is that it operates at constant speed, regardless of load, as set forth in another part of the present report. This has the advantage that if the train is moving at all, it is moving at constant, uniform speed and the train dispatcher thus knows accurately when it will reach a given point. This type of motor is essentially very rugged and will stand much abuse. On the other hand, its demands for power are relatively not as flexible as with the series motor on grades, although it is true that by changing the connections, various definite speed ratios may be obtained which provide some flexibility in this regard. The starting of this type of motor is accomplished by means of resistance and is not efficient, but as this type of motor is usually used for heavy duty, long-distance service with infrequent stops, the starting losses are relatively unimportant.

Power may be supplied for the three-phase induction motors of the type just described, from a single-phase distribution circuit, by means of a phase-converter which consists of a rotating machine mounted in the cab of the locomotive, supplied with single-phase power. This type of apparatus is somewhat similar in design to the phase-balancer already mentioned, which permits single-phase power to be taken from a three-phase power system without unduly unbalancing the load among the phases. This type of apparatus may be of an induction type or a synchronous type as desired.

Regeneration of power may be readily accomplished with either the direct-current or single-phase series-commutator motors by properly manipulating the internal and external connections, and also with the three-phase induction type motor. There are numerous cases of direct-current regeneration by series-commutator motors but no instances of regeneration with the single-phase series motors in the territory covered in this reports, though this may be as readily accomplished, and is extensively employed elsewhere. Electric braking without regeneration may be accomplished with all three types of motor if desired.

A novel motor arrangement has recently been developed wherein power is supplied to the traction motors through a mercury-arc rectifier equipped with grids which may be excited by means of a small distributor mechanically connected to the shaft of the motor. The excitation controls the direct-current output of the rectifier in such a manner that it acts as a commutator, and the main motors thus do not require commutators. The armature is the stator and the field the rotor, fed by slip rings. A very rugged design is possible, and since the control may be accomplished entirely by means of the grid excitation such appurtenances as switch groups and external current-limiting resistance are not required, nor obviously are transformer taps. The power supply being rectified, may be of any frequency. Although commercial experience with this arrangement of apparatus has thus far been limited, nevertheless it gives promise of valuable development.

The multiple-unit car problem is somewhat more restricted than that of the electric locomotive. It is impracticable to equip each motor-car with a motor-generator set to take power from the distribution supply circuit for supply of power for traction motors. The use of phase-converters and three-phase induction motors is also out of the question for motor cars. Cars are thus equipped with series motors, either alternating-current with transformers, or direct-current with series-parallel controllers and resistors, depending upon the type of distribution system chosen.

If direct-current is employed at trolley voltages above 1 200 volts, it has sometimes been found expedient to install four motors on each motor car and to couple permanently together a trailer and motor car so that each unit of motive-power consists of two cars. The four motors are thus started in series as indicated above, and after a reasonable speed is reached, reconnected in series-parallel so that at normal speed with starting resistance cut out, one half the line voltage may be impressed across each motor. Thus if 3 000 volts is used the terminal motor voltage is 1 500 volts, two motors being permanently connected in series.

Single-unit all-motor-car operation with no trailers possesses the advantage of considerable operating flexibility as compared with two-car units because the increment in making up a train obviously is thus one car instead of two. There is also the advantage that if a motor or other piece of apparatus fails on a car, that car may be automatically de-energized, and the train hauled by the other motor-cars without loss of time or risk of damage due to overloading the remaining equipment. Under some circumstances also the saving in costs made possible by concentration of power in motor cars and the use of trailers may offset the advantage of flexibility of all-motor-car operation. This may be especially true in the case of train-control or cab-signal facilities which if applied to each car may involve very heavy expense.

Summary. — The direct-current series-commutator type of motor is, all things considered, the most satisfactory type of motor in itself, but especially if it is supplied from high voltage direct-current distribution circuits the control, in starting by means of external resistance, is a limitation. The direct-current type of traction motor may be operated from a direct-current distribution circuit or from a single-phase distribution circuit by means of a motor-generator set installed on the locomotive; this latter scheme allows a very favorable control arrangement but has the disadvantage of additional facilities on the locomotive, and this scheme is of course not practicable for motor cars. The single-phase motor may be readily adapted for operation from direct-current supply circuits of proper characteristics.

Various types of motors to suit various operating conditions may be supplied from single-phase circuits. Regeneration or electric braking may be accomplished with any of the types of motors discussed.

Conclusion.

An attempt has been made to outline very briefly and qualitatively the advantages and limitation of various systems of power distribution which have been developed for railroad electrification. It is impossible to make any general quantitative statement which would not be misleading, as to relative costs of installation or economies of operation among various individual systems, since local conditions vary so greatly. Each of the several systems represented is operating successfully.

It is of vital concern that there should be standardization of system of power distribution and of design of locomotives and other integral parts of the electrification requirements. To one familiar with the economies which have been made possible by quantity-production, especially in such industries as automobile manufacturing, it is obvious that the unit costs of installation of all factors of electrification will be modified very greatly if quantity-production can be brought about by general standardization of design and manufacture.

It may be said that in general the choice of the most effective voltage is dependent upon the kind of traffic, weight of trains, and extent of the territory to be electrified. With service consisting of relatively frequent trains over a short route — service analogous to urban rapid-transit operation — low voltage is undoubtedly satisfactory, though it is universally agreed that such voltage is inadequate for general railroad operation. As the weight of individual train units (either passenger or freight) increases, and as the electrified territory is extended, it is logical to adopt higher voltage. For heavy trains operating over long distances, the maximum practicable voltage is undoubtedly the most economical and advantageous. The data set forth in the table in the appendix indicate the tendency in this direction.

Among the half-dozen voltages used in direct-current distribution, the potential chosen in each instance was undoubtedly picked as being the most efficient for the particular service required. Direct-current voltages above 3 000 volts are not in commercial use in the territory covered in this report, higher voltages than this being alternating-current. It has been found that a nominal potential of 11 000 volts, twenty-five cycle, single-phase is sufficiently flexible in itself to handle, without modification, all kinds of railroad service, from single-car passenger trains operating in interurban service to twelve-thousand-ton freight trains and a concentrated demand in a single train of as high as twenty-thousand horse-power. It is peculiarly adapted to general service in extended territory where heavy trains are operated.

In any integral territory where railroad operation is so coordinated that there is interchange of motive-power among railroads, or where there is joint terminal or track operation among various operating units or companies, it is essential, if satisfactory operation is to be maintained, that a unified system of power distribution for electrification be chosen. Standardization in this respect is nearly, if not quite as important as standardization of such items as air brakes and draft gear, to say nothing of track gauge itself. It is true we cannot visualize the future, and that we cannot now know what developments during the next few years may bring forth. It may be found desirable, as demands for railroad service grow, to operate power distribution systems at far above 11 000 volts. We shall undoubtedly see direct-current power transmission at voltages higher than those at which we now transmit alternating-current power, and the commercial introduction of facilities which will reconvert this high-voltage direct current to alternating current at any desired frequency or set of frequencies for use locally. It would not be logical however to postpone standardization until ultimate development is attained. If such philosophy were to control, there would be a sad lack of progress indeed. The present opportunity is thus seized to urge strongly the immediate standardization of traction power systems, not in a single system of distribution throughout the world, but within each territory where unified railroad electric operation or interchange of motive-power now exists or is likely to be desirable in the future. Such standardization has already taken place in some territories, and if it can be further accomplished, there will undoubtedly result a not inconsiderable stimulus in the development of the art of railroad electrification and of the extension of territory electrified.

IV. — SAFETY PRECAUTIONS.

It has been assumed that this discussion is limited to the safety to persons only, and not to property, though it is often difficult to differentiate between these two problems, which are closely related. The discussion is also limited to precautions applying to electric traction purely, that is, the use of electricity specifically in railroad electrification service. Neither the problems encountered in the use of electricity for general purposes, nor the precautions in connection with railroad operation other than as affected by the application of electricity, will therefore be discussed.

Electric operation of railroads may be divided into three general departments :

1. Power generation;
2. Power transmission and distribution;
3. Motive power.

Many safety precautions are of course common to all these departments or branches of operation, but other provisions are by nature applicable to one only. Miscellaneous problems, such as communication circuits in electrified territory, are also given consideration.

Power generation. — Many railroad electrification installations utilize purchased power entirely, and such railroads do not operate power plants of their own. In these cases obviously there are no precautions in which the railroad is interested, which involve power plant operation. Even in instances where the railroad owns and operates its power generating facilities, the precautions which should be taken are usually identical with the safety practices generally necessary in power plants which are operated commercially, and are thus outside the scope of the present discussion.

Perhaps the chief operating difference between a commercial power plant and a power plant designed primarily to carry railroad load is in the circuit protective apparatus. The necessity for collecting power at high speed by means of moving contacts, and the fact that the distribution conductors are necessarily relatively close to the ground or are otherwise in vulnerable locations under highway bridges, etc., both result in the occurrence of short-circuits or grounds relatively frequently, as compared with such abnormal conditions generally experienced in commercial supply circuits. In addition, the fact that the track rail or ground is utilized for the distribution circuit return, results in causing abnormal conditions to be quite severe, and this means that the protective circuit-breakers may be required not only to operate relatively frequently, but to break relatively heavy short-circuit currents, as compared with similar apparatus in commercial stations of equal capacity. It is thus sometimes desirable to operate the circuit-breakers at a higher degree of maintenance than is normally the practice in commercial plants, subjecting them to more frequent and careful inspection.

Power transmission. — In the field of power transmission the same considerations apply generally as in power generating plants. The customs and practices which have been adopted by commercial companies in handling high-voltage circuits are equally logical and necessary in handling railroad transmission circuits. In many instances it is true that the high voltage transmission is actually owned and operated by the company supplying the power, and the railroad thus has no responsibility for them.

The transmission circuits may be open-wire or may be in cable, either underground or hung aerially from a messenger. It is a rule in all instances, so far as information regarding railroad circuits in cables is available, to de-energize and to « earth » or « ground » all conductors while work is being performed upon them. In instances where high-voltage open-wires are involved, no work is usually permitted in the immediate vicinity of normally energized wires, unless they are de-energized and earthed or grounded. Some railroads which operate high-voltage circuits underground in cables de-energize the circuit while men are working near the cable. This precaution is not universally considered necessary, however.

In some instances when the transmission circuit is absolutely isolated electrically from the ground, and the neutral is not grounded or earthed, it may under some circumstances be permissible to work upon one conductor of either a single-phase or three-phase open-wire circuit by earthing or grounding that conductor, of course carefully keeping clear of the other conductors of the circuit. This method of operation of course would not apply if the neutral of the circuit is grounded or earthed even through a high resistance.

Some organizations permit work upon high voltage circuits while they are alive, utilizing special tools on the end of long treated wood sticks. Treated wood platforms are sometimes used in the same way, the operators standing on the platform, electrically isolated from all material other than the conductor upon which they are to work. Such operation requires very highly trained men and is usually of value only if it is absolutely necessary to maintain service continuously over a given circuit. In railroad power supply it is usually practicable to utilize an alternative method of feed, and to de-energize and earth or ground all circuits upon which work is to be performed.

The routine of accomplishing the de-energizing of transmission circuits in order to work upon them is usually similar to that in connection with distribution circuits, and is described below. It is essential that no work be allowed under these circumstances until the conductors have been earthed or grounded, not only to guard against error, or accidental energizing of the conductors, but also against induced voltage. Neon tubes, or other glow devices are sometimes used to indicate whether a circuit is still alive or not.

The process of « earthing » or « grounding » railroad supply circuits before working upon them is usually relatively simple compared with that used for ordinary commercial circuits, because there is usually opportunity for a definite or positive metallic connection to the track rails, on to a steel structure or conductor which is positively connected to the track rails. The grounding device generally consists of a length of insulated conductor, attached to a metal hook at the end of a wood stick, and having a clamping device at its other end. It is necessary for the operator first to fasten the clamp device to a properly grounded structure and then hook the ground conductor over the conductor on which he is to work, utilizing the stick provided for the purpose in order to keep his body below and clear of any arc which may occur if he should through error ground the conductor when it is alive.

In the design and construction of power transmission as well as distribution systems, it is necessary to take into account the most severe condition of wind and ice loading which may be encountered, and to so design the installation that there will be no mechanical failures under any reasonable mechanical loading. Needless to say, the insulators should be adequate to withstand the mechanical and electrical loading, including surges, to which they may be subjected. Other items, such as proper spacing between conductors to prevent their swinging together, should also be considered. Some railroads make a practice of increasing the insulation at highway crossings and at station platforms as an added protection against failure at such points.

Traction substations. — The substation safety precautions are in many respects analogous to those at power plants. It is sometimes the case, however, that the personnel in control of a substation may not be as highly trained as is that in charge of power plants and for this reason added precautions for safety may be found desirable. This is especially true as a man may be assigned to operate a substation alone, without assistance. In such instances, it is desirable that there be no possibility of the operator placing himself in danger from injury due to faulty equipment or to error in judgment. To this end, certain compartments and cells are often closed away from the rest of the substation and operators are forbidden to enter unless power has been removed from the apparatus within these enclosures. Indeed it is sometimes found desirable to automatically interlock such locations so that it is physically impossible for the operator to obtain access to any compartment until the power has been removed from the apparatus within that compartment. Warning signs and indication signals or lights are also usually provided.

Substations are usually provided with switches or circuit-breakers to control the incoming power and the outgoing feed to the distribution system. These circuit-breakers may be under the control of the substation operator or, if the substation is controlled from a distance, by the distant operator, or from the power-director's switch-board. In any case it is necessary that when the switches are to be inspected or repaired, they be entirely de-energized and inoperable. The maintainer must assure himself that the switches upon which he is to work have been opened and that the control handle is properly tagged by the operator, also that all switches feeding the circuit-breaker on which he is to work have been opened, and that the normally energized parts of the circuit are grounded or earthed, before he touches the breaker. There si usually provided a switch in the control circuit, which the maintainer can open while he is at work, to prevent accidental closing of the circuit breaker.

It goes without saying that unauthorized or unqualified persons should at all times be kept away from substation equipment.

The British Home Office Regulations are followed by many companies within the British Empire, while the United States Bureau of Standards National Electrical Safety Code governs in the United States, in addition to regulations promulgated by regulatory bodies in various states locally. Many railroads have elaborate safety rules of their own which supplement the general rules issued by the governmental agencies.

Distribution system. — There are two major types of distribution systems :

1. Overhead contact wire, and
2. Third rail.

(In a few installations in the vicinity of London, England, there is a « fourth rail » for the return traction circuit to keep it out of the running rails and thus out of the ground.) The problems connected with these two types of distribution are quite diverse and are discussed separately.

Overhead contact system. — This, as its name implies, includes a contact-wire over the electrified tracks. The safety precautions which are necessary on account of the presence of this conductor are in general the same whether the distribution power is alternating current or direct current, or whether it is at 11 000 volts or 600 volts, except that at lower voltages it may be permissible to work from a properly protected platform with the system alive, provided double insulation is employed so there is always one insulator between the the maintainer and ground, while with high voltage, except for a relatively limited class of work, the system should be de-energized and grounded before work is performed on or near the conductors. Rubber gloves are sometimes used for work at lower voltages, but seldom for voltages above 4 000.

The height of the contact wire above the top of rail should be as great as possible wherever men are to be allowed upon the tops of cars beneath it. Some railroads which are electrified with overhead contact system prohibit men from riding on the tops of cars on the main line, even though the wire may be nominally sufficiently high for safety; because on account of overhead highway crossings there may be instances of low clearance which might be dangerous to riders on tops of cars of a rapidily moving train. Some railroads protect their crews by warning lights or signals placed by the roadside to indicate low wire, giving opportunity for the trainman to get down into safety.

In yards where movements are relatively slow, and when for purposes of convenience of operation, it is desirable for men to climb upon cars, the clearance is maintained as high as possible and signs are usually installed to warn men when approaching any necessarily low wire.

Besides the protection of trainmen from the energized overhead wire, it is necessary to consider carefully the protection of the public. The contact wire necessarily passes under highway bridges installed over track, and in deep, narrow cuts the contact wire and associated feeders may be relatively accessible to trespassers or to the public on adjacent property. In all cases where there is possibility of direct contact or of contact through the dropping or throwing of material upon the live conductors, screens, signs, guards or other protective measures should be employed, One of the greatest problems where the railroad line is not thoroughly fenced in, is from trespassers, and it is sometimes necessary to install guards to prevent such persons from actually climbing structures and coming in contact with live conductors. Some railroads paint warning signs on all their poles and structures as a matter of routine.

At crossings with highways at grade (« level crossings ») the height of the contact wire above the roadway should be such that there is no possibility of physical contact with loads of any reasonable height passing on the highway. Some railroads install gauges on the highway at either side of each level or grade crossing te prevent accidental contact from vehicles which are too high to pass safely under the power distribution conductor.

It is usually desirable that metal structures supporting live contact conductors and associated feeders by means of insulators be electrically connected to the track rail, so that in the event of an accidental contact or a defective insulator, the structures will not be energized, but will be maintained as nearly as possible at ground or rail potential. The connection to the rail should be sufficiently large so that it will not be burned off in the event it is called upon to carry a large short-circuit current.

In some cases it is not desirable on account of electrolysis or for other reason, to connect the supporting structures to the rail. In these cases a device is inserted in the ground conductor consisting of a very short air gap. This gap is normally open, but any abnormal voltage causes a spark to jump and immediately establishes electrical connection and ready rail return path to the substation.

Needless to say, the track rails should be carefully bonded and the bonds well maintained, to insure the integrity of the return circuit at all times and prevent high rail voltages which might be dangerous to men working on the track or to persons boarding or leaving trains.

In addition to the protection of train crews and of the public in preventing access to live members of the overhead contact system, careful consideration is necessary for protection of the maintenance crews whose duties require that they perform work upon the conductors which are normally energized. It is usually desirable for various reasons, that any work which is necessary upon or near normally live facilities should be done with the facilities de-energized and grounded or earthed. The grounding is especially important, because from the nature of the system it is often possible that any de-energized section may be accidentally energized, also considerable induced voltage may be picked up on a dead, ungrounded section on high-voltage alternating-current systems. It is fortunately true that grounding to the running rails eiher directly, or through properly connected structural steel supports, may be easily and positively accomplished, and workers thus adequately protected against faulty operation of circuit breakers or other accidental energizing of the circuits upon which they are working. The process of earthing conductors or grounding them to the track rails is similar to that described above.

Under some circumstances if care is taken, it may be permissible to work on circuits of the distribution system while they are alive. For instance, especially on low voltage circuits, a properly insulated platform mounted upon a car may be safely used for working upon the contact system alive, provided adequate precautions are taken, such as avoiding contact with any grounded structure, car roofs, etc. as outlined above.

It may be permissible also to perform certain certain work « alive » on high voltage distribution systems, though the scope of such work is of course limited. Treated wood ladders are used and but one man is allowed upon a ladder at a time. Passing material from the ground to the ladder should be prohibited under these conditions in order to prevent accident which might be caused by flow of current on account of reducing clearance from energized circuits to ground.

Needless to say only properly qualified men should be normally allowed to closely approach energized facilities. If it is necessary that non-qualified men, such as painters, carpenters, etc. work in the neighborhood of energized wires, a qualified man is assigned to protect them. It is the duty of this man to see that all necessary wires are de-energized and properly grounded or earthed as described above, before authorizing work to begin, and to constantly watch the progress to insure that those under his protection remain a safe distance away from all energized wires or other parts.

Third rail. — The problems in connection with third-rail protection are quite different from those of overhead contact systems. While the voltage is usually lower than is often the case with overhead contact systems, the fact that live parts are within a few inches of the ground makes necessary a number of considerations.

When the railroad runs through open country, it is usually necessary to protect the third-rail from accidental contact by trespassers and from animals, such as dogs, which may cross the tracks. It is usual to locate the third-rail outside the track, and it is of course necessary to so place it that it will clear all equipment which may be run over the track. Four forms of such protection are common :

1. Cover the top and two sides of the rail, leaving the lower surface only, bare for the contact shoe;

2. Cover the top, bottom and two sides, leaving an open slot in one side between top cover and the upper surface of the third-rail, through which the contact device may operate;

3. Cover two sides of rail from a plane above the upper surface to a plane below the lower surface. The contact device is thus operated vertically between the covers and against the top surface of the rail;

4. A single wood cover is sometimes installed directly over the rail, projecting either side sufficiently far to reduce danger from accidental contact with the sides of the rail.

If the railroad right-of-way is accessible only to employees, such rail protection is sometimes omitted, but this does not protect the trackmen using metal tools from accidental contact with the live rail.

The voltage of third rail located near the ground is usually so low that maintenance work of a minor nature may be performed while the facilities are alive, provided rubber gloves and mats and insulated tools are employed. In some instances when the third rail is de-energized for working, it is grounded or earthed, but in other cases this precaution is not taken.

Signs and warnings painted at frequent intervals on the rail guard warn unauthorized persons who may be on the right-of-way and remind railroad employes constantly of the danger of accidental contact. At station platforms and near highway crossings at grade, the physical protection and warning signs are often increased.

At highway crossings at grade (level crossings) the third rail is necessarily discontinued, and a jumper installed under the highway to carry the traction circuit. Care must be exercised to insure the integrity of this jumper, for faulty insulation may allow serious leakage of current and may thus raise the ground voltage in the vinicity to a point which may be dangerous to animals and others passing on the highway.

It is usual at loading platforms and other places where loading takes place, to install the third-rail on the opposite side of the track.

Third-rail in large classification or switching yards is not desirable on account of the necessity of constantly climbing on and off cars on the part of the yardmen, and coupling and uncoupling of cars. It is thus preferable to accomplish power distribution by means of overhead contact conductors. These should be elevated above the track sufficiently to permit yard men to stand on top of the cars without coming in contact with the live conductors.

The power for third-rail is usually controlled by the power-director through remotely operated switches, just as the overhead contact system is usually operated, so that when a section is to be cut out of service for maintenance or other purposes, the operation is performed through the power-director who insures that switches are tagged out to prevent premature closing.

It is sometimes desirable for the crew which is about to work upon third rail, to determine whether or not it is alive. This is accomplished by means of a bank of electric lamps or other device. For higher voltage circuits, neon tubes are sometimes employed for this purpose.

Under some conditions, especially in tunnels, an emergency may make it necessary to cut off the power from the third rail manually. For this purpose push-buttons or cord devices are supplied along the route which may be operated by the person most conveniently located at the time, opening all the circuit-breakers feeding the sections, and de-energizing the rail.

Electric motive power. — The safety precautions considered in connection with electric locomotives and multiple unit cars are primarily for the protection of the crews, because in general it is possible to arrange apparatus so that passengers and other persons not connected with maintenance and operation cannot come in contact with live parts.

One of the most important considerations is safety upon the roof of the equipment, especially when overhead contact wire distribution is employed. Strict regulations are usually promulgated prohibiting all persons from going on the roof without first insuring that the pantographs or other power collecting devices are all lowered away from the supply conductor, locked down and grounded or earthed. In some instances access to the roof is made physically impossible unless this has been done.

It sometimes happens that locomotives which normally take power from third rail, are equipped with an overhead pantograph or trolley device to take power alternatively from overhead supply conductors. Such devices are obviously alive when the shoes are in contact with the third rail. It is thus usually desirable to issue instructions prohibiting all persons from going on the roof while third rail shoes are in contact with the third rail. Care is also necessary to insure that it is understood that third rail shoes on one side of the equipment are always alive while those on the other side are in contact with the energized third rail.

Trouble may develop on a locomotive or motor-car, which is not properly cleared by the protective devices provided for the purpose. For such emergency there is sometimes provided an arrangement which permits an absolute short-circuit to be established manually between the supply circuit and the running rail. This arrangement is usually applied with third-rail distribution only.

In third-rail territory if it is desired to disconnect the third-rail shoes of an electric locomotive or motor car from the third-rail, wooden paddles may be inserted between the shoes and the rail. These paddles if properly installed, de-energize the equipment throughout the locomotive.

Within the motive power itself, there are various facilities which are energized when the locomotive or car is in operation, and with which physical contact may be dangerous. Is some instances these facilities are protected by warning signs and in other cases the apparatus is installed in compartments, the doors of which cannot be opened unless the locomotive or car is entirely de-energized.

Electric locomotives and multiple-unit cars should be completely dead when they are within the shop or engine terminal. The problem of traction power within the shops is thus an important one, for it is sometimes not convenient to insure that all the personnel are clear whenever it is desired to move a single unit of motive power. This problem is sometimes solved by utilizing an independent unit of motive-power, such as a steam locomotive or storage battery car, for moving equipment within shops; and sometimes by flexible low-voltage jumpers.

A much considered question is the use of circuit-breakers on locomotives and on multiple-unit cars to clear the circuit in the event of trouble on the motive-power unit. Some railroads have installed such circuit-breakers, and some (especially where alternating current at high voltage is employed) have left off all devices of this kind, with the idea that if a short-circuit or ground occurs, the circuit-breakers protecting the supply-circuit at the nearest substations or switching stations will open, after which the pantograph or collecting device may be automatically dropped clear of the overhead wire. If circuit-breakers are installed on the locomotive for protective purposes, it is usually desirable that the circuit-breakers be closed before the power-collecting device is placed in contact with the supply conductors. If a short-circuit occurs on account of defective equipment when the collecting device is raised, the operator is thus out of the way of possible trouble.

The use of power-jumpers at contact-line potential between cars of a multiple-unit train is common. In some systems each car is a motor-car, and is thus self-contained so far as operating apparatus is concerned. Nevertheless in order to maintain power continuously at gaps in the distribution system, it is sometimes found to be desirable to connect the power-busses of the cars in a train together. If trailer-cars are operated, power-jumpers are necessary from motors-cars, for operation of car heaters, lights, etc. These jumpers sometimes extend throughout the train and sometimes merely run to an individual trailer or two. Such jumpers if the voltage is not too high are usually installed in cable and are plugged into receptacles at either end platform. Locks are usually provided to insure that the plugs are not pulled from the receptacles unless all power has previously been cut off. It is sometimes desirable to apply jumpers at high voltages (over 3 000) between cars. Such facilities are usually in the form of an exposed contacting device, usually air-operated, mounted on the roof at the end of the car, which coordinates with a similar device on an adjacent car. Extreme care and thorough education are necessary to insure that it is understood that certain apparatus on the cars may be energized through train jumpers, and that contact with such apparatus is as dangerous (if jumpers are in service) as if the shoes on the car itself were in contact with the supply circuit.

In order to guard against sudden illness or somnolence on the part of the driver of a motor-car train, a so-called « deadman's-handle » is supplied on the controller which operates the traction motors. This requires a continuous manual pressure by the engine-driver upon the controller handle, which if released will cut off the power and apply brakes. Electric passenger locomotives are sometimes equipped with a similar device, though with two men in the cab it is not as essential as with motor-cars where there is but one man. On long freight trains a sudden brake application is not desirable, and the dead-man's control feature if installed, therefore does not set the brakes on freight trains, but operates a loud audible signal.

The Industrial Safety Survey of the International Labor Office, Geneva Switzerland, Vol. VII, No. 4, July-August 1931, in discussion covering the subject of one-man operation of self-propelled vehicles, concludes as follows :

All things considered having regard to the constructional features of the safety controllers, to practical running experience and the theoretical conclusions to which they give rise, it would appear that the time is not ripe for an international discussion as to whether the one-man system should be generally recommended or generally condemned. Rather must the decision on the introduction or non-introduction of one-man driving be left to the individual railways themselves since, as visibility, gradients, curves and weather differ wholly from one to another, they alone are in a position to decide whether the one-man system is suited to their electrificied sections and will afford the maximum of safety.

Miscellaneous. — On electrified railroads adequate communication facilities are a necessity. Delay in transmitting information to the load-dispatcher or power-director, or in transmitting his instructions may have very serious consequences. A sufficient number of telephone or telegraph circuits to handle the business, and telephone stations or instruments well distributed throughout the electrified zone are thus very desirable. This service is supplementary to the requirements of normal railroad operation in which adequate communication plays an important part.

Paralleling the traction power distribution system as they often do over perhaps relatively long distances, electromagnetic and electro-static induction in the communication circuits present important problems. Various means of coordination are employed to insure reliability of communication which are outside the scope of the present discussion. Care must be exercised in working upon the communication circuits to guard against induced voltages in the conductors, which may be sufficiently high to be a source of trouble unless proper precautions are taken. A relatively slight electric shock may throw a man off a pole or platform. If possibility of such a shock exists, rubber gloves should be used.

A safety precaution which has been found desirable, especially where there is danger of stray electric current causing sparks, is in the loading and unloading of volatile inflammable liquids, such as gasoline (petrol). In such cases, and to prevent electro-static discharges, the track rail on which the tank car stands should be isolated from the rest of the yard, or from the main line, by means of insulated rail joints, and electrically grounded. There should be in addition, effective electrical connection between the track-rail and the oil pipes or tank, and between the tank car and the piping to which it may be connected.

One of the possible sources of trouble where electrical apparatus of any kind is operated, is from fire. Defective apparatus may start a fire which if not handled properly may result in damage and hazard to the persons handling the facilities. Trouble of this kind may occur in spite of all precautions. It is therefore desirable to install in power plants, substations, locomotives and at other points where experience indicates it is desirable, suitable fire-extinguishers, and to instruct and train the personnel in handling them. Various types of fire may occur, — perhaps the most serious is an oil fire caused by a defective oil-cooled transformer or oil circuit-breaker. Combustible insulation may also cause difficulties. It is desirable, other things being equal, that any fire-extinguishing medium be non-conductive of electric current, because live conductors may be present even though every effort be made to de-energize all apparatus in the vicinity. Insulation may be another source of difficulty. Carbon tetrachloride and liquid carbon dioxide, extinguishers, are among the types of non-conducting fire extinguishers supplied when electrical apparatus is used. Sand buckets are often used. If the importance of the facility warrants and conditions permit, a generous supply of water is made available. Fire-foam and soda-and-acid extinguishers are effective in putting out fires, but the streams may be conductors.

Many electrified railroads run through densely populated territory and it sometimes happens that a fire may occur on property adjacent to the railroad right-of-way. Although under normal conditions of city supply of water it would be perfectly safe for a stream from a hose to impinge upon energized circuits, nevertheless there is not always insurance that fresh water will be used, and so it is sometimes arranged with the local fire departments that power will be removed from the system before active fighting of an adjacent fire is allowed to begin.

A precaution which should be included in safety regulations, is in the handling of the wrecking crane or derrick in electrified territory. A properly qualified electrical worker should be assigned to the wrecking crew to insure that the derrick boom is not raised into overhead wires unless they are first de-energized and earthed or grounded. It sometimes happens that an electric locomotive becomes derailed. Care should be taken to insure that if all the wheels of the locomotive are off the track, the power from the supply-line is not applied to the locomotive in the attempt to re-rail it, because if there is not an adequate return path through a rail connection, the whole unit may be energized with the full voltage of the supply power and serious injuries may result.

In spite of all possible precautions it sometimes happens that persons engaged in electric traction may come in contact with energized circuits. Many railroads have first-aid facilities available at strategic places, and the personnel is often fully instructed in the best methods of resuscitation from electric shock, in treating electrical burns, and in otherwise caring for injured comrades until skilled medical assistance is available. It is through continuous training in this direction and continuous attention to safety precautions and education that the handling of electric traction facilities may be accomplished with maximum safety.

APPENDIX A.

Below is presented a summary of data of a few of the electrified railroads of outstanding interest in the territory covered by the present report, — North and South America, Cuba, Great Britain (Dominions and Colonies), China, and Japan, and chief reasons controling the decision for electrification. A complete list cannot be presented at this time on account of the limitation of space, but an attempt has been made to list typical examples in various parts of the world included in the assignment. The list has been somewhat arbitrarily chosen and it is hoped it will form a basis for full discussion and that numerous items of interest will be presented which have necessarily been omitted in compiling the report. The data have been compiled from answers to questionnaires issued to various electrified railroads, supplemented by information contained in reports of the Railway Electrification Committee, National Electric Light Association, U. S. A.

Reference is made briefly to the following railroads :

North America.

Canada.

1. Canadian National Railways — *a*) St. Clair River; *b*) Montreal.

United States.

2. Baltimore and Ohio Railroad — *a*) Baltimore, Maryland; *b*) Staten Island, New York.

3. Boston and Maine Railroad — Hoosac Tunnel, Massachusetts.

4. Butte, Anaconda and Pacific Ry. — Butte-Anaconda, Montana.

5. Chicago, Milwaukee, St. Paul and Pacific R.R. — Harlowton, Montana to Avery, Idaho, and Othello to Tacoma and Seattle, Washington.

6. Cleveland Union Terminal — Cleveland, Ohio.

7. Delaware, Lackawanna and Western R.R. — Suburbs Hoboken, N.J.

8. Great Northern Railway — Skykomish-Wenatchee, Washington.

9. Illinois Central R.R. — Suburbs Chicago, Illinois.

10. Michigan Central R.R. — Detroit River Tunnel.

11. New York Central Railroad — Suburbs New York, N.Y.

12. New York, New Haven and Hartford R.R. — New York to New Haven, Conn.

13. Norfolk and Western Railway — Bluefield-Iaeger, West Virginia.

14. Pennsylvania Railroad — *a*) New York-Philadelphia and suburbs Philadelphia, Pa.; *b*) Suburbs New York-Long Island; *c*) Long Island, freight.

15. Reading Company — Suburbs Philadelphia, Pa.

16. Virginia Railway — Mullens, West Virginia-Roanoke, Va.

Mexico.

17. Mexican Railways — Esperanza-Paso del Macho.

Cuba.

18. Hershey Cuban Railway — Havana-Matanzas.

South America.

Argentine.

19. Buenos Aires and Western Railway — Buenos Aires-Moreno.

20. Central Argentine Railway — Buenos Aires-Tigre East.

Brazil.

21. Paulista Railway — Jundiahy-Rincao.

Chile.

22. Chilean State Railways — Valparaiso, Los Andes, Santiago.

Great Britain, Dominions and Colonies.

British Isles.

23. London, Midland and Scottish Railway — *a*) Suburbs, London; *b*) Manchester-Holcombe Brook; *c*) Manchester-Altrincham; *d*) Liverpool, Southport, Crossens, Omskirk.

24. London & North Eastern Railway — *a*) Newcastle-Tynemouth; *b*) Shildon-Newport.

25. Southern Railway — Suburbs London; Brighton and Worthing.

Australia.

26. New South Wales Government Rys. — Suburbs Sydney.

27. Victorian Railways — Suburbs Melbourne.

India.

28. Bombay, Baroda & Central India Ry. — Colaba-Borivli.

29. Great Indian Peninsula Railway — Suburbs Bombay.

New Zealand.

30. New Zealand Government Railways — *a*) Christchurch-Lyttleton; *b*) Arthur's Pass-Otira.

South Africa.

31. South African Railways — Pietermaritzburg-Glencoe.

Japan.

32. Chichibu Railway — Kumagya-Kagemori.

33. Japanese State Railways — Tokio-Yokohama and suburbs.

North America.

Canada.

1. — *Canadian National Railways (Government-owned).*

a) St. Clair River Tunnel, Port Huron, Mich. to Sarnia, Ontario.

Electrification started 1908.

Route miles 4. Track miles 12.

Power distribution single-phase, overhead catenary, 3 300 volts.

Locomotives 9.

Power-purchased — steam sources, delivered 60 cycles, three-phase to frequency-changers at one substation owned and operated by the power company.

A railroad-owned steam power plant acts as standby to generate power at 25 cycles, single-phase.

This is a typical tunnel electrification. Although the tunnel is only about 6 000 feet long, ventilating conditions were very difficult under steam operation. Both passenger and freight trains are handled electrically. Locomotives are changed at both ends of the electric zone.

b) Montreal Terminal to Cartierville and St. Eustache.

Electrification started 1918.

Route miles 17. Track miles 32.

Power distribution direct-current, overhead catenary, 2 400 volts.

Locomotives — 6 passenger.

Motor cars 2.

Power purchased — steam and hydro-electric sources, delivered 60 cycles, three-phase, 11 000 volts to motor-generators in one substation owned and operated by the railroad.

This is a suburban and terminal and tunnel electrification, carrying freight and passenger traffic. Elaborate plans are under way for new and improved terminal facilities, both passenger and freight, in the City of Montreal. In view of the proposed use of air-rights over tracks, electrification will play an imporant part in the development.

United States of America.

2. — *Baltimore & Ohio Railroad.*

a) Baltimore Tunnel, Maryland.

Electrification started 1895.

Route miles 4. Track miles 9.

Power distribution direct-current, third-rail, 600 volts.

Locomotives — passenger or freight 8.

Power purchased — steam and hydro-electric sources, delivered 25 cycles, three-phase, to synchronous converters at one substation owned and operated by the railroad.

This project, the first steam railroad electrification in the United States which employed locomotives, is a typical tunnel electrification, handling both passenger and freight. Power was originally produced by the railroad, but the railroad plant was superseded in 1909. Electric locomotives haul eastbound trains through the tunnel on ascending grades with steam locomotives non-operative, and return light. Westbound trains without electric locomotives coast down-grade through the tunnel. This method of operation avoids breaking steam locomotive runs.

b) Staten Island Rapid Transit Lines, New York City.

Electrification started 1925.

Route miles 22. Track miles 50.

Power distribution, direct-current, third-rail, 600 volts.

Multiple-unit cars — 90 motor cars, 5 trailer.

Power purchased — steam sources, delivered 60 cycles, three-phase, to synchronous converters in six substations owned and operated by the railroad. One of the substations is manually controlled, five automatic with supervisory control from the manual substation.

This electrification was installed for suburban passenger service, primarily as a result of legislation. As the name implies it is in many respects analogous to a rapid-transit system.

3. — *Boston & Maine Railroad.*

Hoosac Tunnel, North Adams, Mass.

Electrification started 1911.

Route miles 8. Track miles 21.

Power distribution single-phase, overhead catenary, 11 000 volts.

Locomotives — 7 passenger or freight.

Power purchased — hydro-electric sources, delivered 25 cycles, single-phase, to two switching stations owned and operated by the railroad.

This electrification is a typical tunnel installation. Steam locomotives are hauled, non-operative, with their trains (either passenger or freight) through the tunnel, thus avoiding braking steam locomotive runs. The power is generated in a hydro-electric plant, a twenty-five and a sixty-cycle generator being mounted on the shaft with the water turbine so the unit may be operated as a frequency-changer, if desired. The railroad load is the only twenty-five cycle load. Previous to the electrification, operation through the tunnel was very difficult, even with oil-burning locomotives and an elaborate ventilating system. Electric operation allows longer trains to be hauled through the tunnel more frequently than with steam.

4. — *Butte, Anaconda & Pacific Railroad.*

Butte to Anaconda and branches.

Electrification started 1913.

Route miles 38. Track miles 122.

Power distribution direct-current, overhead catenary, 2 400 volts.

Locomotives — passenger 1, freight 27.

Power purchased — hydro-electric sources, delivered 60 cycles, three-phase, to three-unit motor-generators, owned by the railroad, at two substations owned and operated by the power company.

This electrification carries both passenger and freight services. Increased length of trains and increased speed is obtained with the electric operation. There is also considerable fuel saving, as waterpower is readily available in that territory and fuel relatively expensive. An interesting operating feature is the heating of passenger coaches electrically, the coaches used in the electric zone being especially equipped for this purpose. It has been stated that electric operation made possible a saving on the order of 20 % per year on the added investment required, based on costs immediately before and after electrification was started.

5. — *Chicago, Milwaukee, St. Paul & Pacific Railroad.*

Harlowton, Montana, to Avery, Idaho, and Othello to Tacoma and Seattle, Washington.

Electrification started 1914.

Route miles 659. Track miles 884.

Power distribution direct-current, overhead catenary, 3 000 volts.

Locomotives — passenger 15, freight 42.

Power purchased — hydro-electric sources, delivered 60 cycles, three-phase, to motor-generators at 22 substations owned and operated by the railroad. The transmission is owned and operated partly by the power companies and partly by the railroad. The substations are all attended.

This electrificaton carries both passenger and freight. Locomotive runs were lengthened when electric operation started, and a number of engine terminals discontinued. Subsequent developments have shown that this might have been done eventually with steam operation by reason of recent improvements in steam locomotive design and operation, even if electrification had not taken place. A very definite advantage has been obtained by regenerating power on long descending grades. The power thus returned to the line amounts to between twelve and fifteen per cent of the energy used. Maintenance charges for rolling stock have been gradually decreased, especially with respect to brake rigging and draft gear on both freight and passenger cars. Fuel saving has been relatively high, as abundant water power is readily available. An analysis of savings due to electric operation soon after the start of electric service, based upon the steam operation displaced, indicated about 10 % per year (over and above interest and depreciation charges) on capital invested.

6. — *Cleveland Union Terminal Company.*

City of Cleveland, Ohio.

Electrification started 1930.

Route miles 17. Track miles 65.

Power distribution direct-current, overhead catenay, 3 000 volts.

Locomotives — passenger 22.

Power purchased — steam sources, delivered 60 cycles, three-phase, to motor generators at two substations owned and operated by the railroad company, remotely controlled.

This electrification carries passenger service only. Steam locomotives are uncoupled at either end of the electrified zone and electric locomotives substituted for transit through the city. The electrification has enabled the company to utilize for revenue purpose, space over the passenger station tracks. In view of the fact that the « terminal » is located in the heart of the city, the air rights are of great value. The removal of passenger facilities from the area along the lake front has permitted expansion of freight facilities on the land formerly used for the passenger tracks and terminal. While this is perhaps not a direct credit to the electrification, it may be said that locating the passenger station in the heart of the business district, where it now is, would have undoubtedly been open to objection under steam operation.

7. — *Delaware, Lackawanna & Western Railroad.*

Suburban territory Hoboken, New Jersey.

Electrification started 1930.

Route miles 68. Track miles 158.

Power distribution direct-current, overhead catenary 3 000 volts.

Multiple-unit cars — motor-cars 141, trailers 141.

Locomotives three-power freight — 2.

Power purchased — steam and hydro-electric sources, delivered 60 cycles, three-phase, to mercury-arc rectifiers at five substations owned and operated by the railroad. 4 substations are manually operated and 1 remote.

This electrification has resulted in speeding schedules and improving service. A tunnel immediately outside the terminal presented some limitations under steam operation. The communities served by the electrification agreed in advance to increases in commuter rates in consideration of improved service. A small amount of freight switching is performed electrically. All « through » service is operated by steam in the electric zone.

8. — *Great Northern Railway.*

Wenatchee to Skykomish, Washington.

Electrification started 1929 (The present system supersedes original electrification installed 1909).

Route miles 73. Track miles 93.

Power distribution single-phase, overhead catenary, 11 000 volts.

Locomotives — passenger 8, freight 5 (2-cab units).

Power purchased — hydro-electric sources, delivered 60 cycles, three-phase, to frequency-changers at two substations, one manually operated, the other remotely controlled from the first. A third supply is generated at 25 cycles, single-phase. Step-down transformer stations are located at five points.

This electrification is an example of an installation originally made for tunnel operation and extended to make possible the economies due to unified operation, and operation over long grades. Furthermore, water power is readily available.

The locomotives are all of the motor-generator type and are equipped for regeneration on descending grades. It is said that about 20 % of the power purchased is returned to the system through regeneration. Passenger trains are heated by means of an oil-fired boiler carried in a trailer car behind the locomotive, and operated by the engineer's helper.

9. — *Illinois Central Railroad.*

Suburban territory and terminal freight yards, Chicago, Illinois.

Electrification started 1926.

Route miles 38. Track miles 154.

Power distribution direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 140, trailers 140.

Locomotives — switchers 4 (supplemented by 6 oil-electric locomotives).

Power purchased — steam sources, delivered 60 cycles, three-phase to synchronous converters and mercury-arc rectifiers at seven substations, owned and operated jointly with commercial service by the power companies.

This electrification was inaugurated originally in accordance with an agreement with the City of Chicago by which the railroad received certain concessions in return for electrifying. The suburban traffic has greatly increased since electrification on account of improved service — (Revenue passengers carried increased 50 % in the first eighteen months of electrification). « Through » passenger and freight traffic is handled by steam into the terminal, but freight switching in the terminal yards is handled electrically and by means of oil-electric locomotives.

10. — *Michigan Central Railroad.*

Detroit River Tunnel — Detroit, Michigan to Windsor, Ontario.

Electrification started 1910.

Route miles 5. Track miles 29.

Power distribution, direct-current, third-rail, 650 volts.

Locomotives (passenger or freight) 12.

Power purchased — steam sources, delivered 60 cycles, three-phase, to motor-generator at one substation owned and operated by the railroad.

This is a typical tunnel electrification. There are heavy grades in the main river tunnel which would make operation under steam conditions difficult. Locomotives are changed at both ends of the electric zone, on both passenger and freight trains.

11. — *New York Central Railroad.*

Suburban territory and city, New York, N.Y.

Electrification started 1906.

Route miles 71. Track miles 368.

Power distribution, direct-current, third-rail, 650 volts.

Multiple-unit cars, all motor cars, 352.

Locomotives — passenger 83, freight 44, switchers 43 (of which 35 are three-power locomotives, oil-electric-storage battery).

Power produced in two steam plants, delivered 25 cycles, three-phase, to synchronous converters in 21 substations, some manually operated and some operated with supervisory control.

This electrification was originally developed on account of legislative action, combined with troublesome tunnel and congested terminal problems, and the creation of very valuable revenue-producing air rights over the passenger terminal tracks in the heart of the City of New York. Electrification made possible the operation of the terminal on two levels with consequent greatly increased track capacity in the closely restricted area. « Through » passenger service is operated electrically in the electric zone, and freight and switching operation is also all electrically operated within the limits of New York City in accordance with legislative action and in return for concession from the city. This allows covering the freight tracks and use of the overhead space for highway purposes.

New York, New Haven and Hartford Railroad trains operate over the tracks of the New York Central Railroad into the passenger terminal.

12. — *New York, New Haven & Hartford Railroad.*

Suburban territory and City of New York, N.Y. and to New Haven, Danbury, New Canaan, Connecticut.

Electrification started 1907.

Route miles 138. Track miles 659. (Including New York Connecting Railroad operated by the New Haven Railroad).

Power distribution, single-phase, overhead catenary, 11 000 volts.

Multiple-unit cars — motor-cars 173, trailers 128.

Locomotives — passenger 78, freight 47, switchers 24, work 1.

Power produced and purchased — mostly steam sources, 25 cycles, single-phase. A small amount of power is generated at 60 cycles, three-phase and supplied to frequency-changers owned by the railroad, installed at one substation which is owned and operated by the power company. A small amount of mutual standby power is interchanged through frequency-changers at two substations with 25 cycle, three-phase, systems.

This electrification was originally developed (see note under New York Central electrification) on account of legislative action, and to solve a terminal and tunnel problem in New York City, with the development of air rights of great value over the terminal tracks. (New Haven trains, normally taking power from an overhead contact wire at 11 000 volts single-phase, operate over the New York Central tracks, where it is necessary to take power from a third-rail at 600 volts direct-current). Extensions of service and in territory have been made from time to time to increase general economies and to obtain the advantages of unified service within an operating district. Practically all sérvice within the electrified territory is handled electrically. « Through » trains are heated in the electric zone by oil-fired boilers, either on the locomotive or on trailers provided for the purpose, for use especially when freight locomotives are employed on passenger or express service. Seven of the locomotives are of the motor-generator type — all the others utilize series-commutator motors. Power is supplied normally to the Bay Ridge Section of the Pennsylvania Railroad. Long Island Division, over which New Haven trains operate.

13. — *Norfolk & Western Railroad.*

Bluefield to Iaeger, West Virginia, and various branches.

Electrification started 1915.

Route miles 56. Track miles 209.

Power distribution, single-phase, overhead catenary, 11 000 volts.

Locomotives — freight 16 (2-cab units).

Power is produced, the steam plant generating single-phase power and delivered to railroad own transmission lines at 44 000 and 88 000 volts. An interchange connection through a frequency-changer for mutual standby is maintained with a commercial power company. Either half of this set, disconnected from the oher by a mechanical clutch, may be independently operated as a synchronous condenser on its own system. A mutual standby single-phase connection is maintained with the Virginian Railroad.

This electrification carries very heavy coal traffic, over long heavy grades. It was originally installed to make unnecessary the supplementing of long single-track tunnels which limited seriously the capacity of the railroad. Extensions were subsequently made to unify the operation. Regeneration is employed on descending grades. The locomotives are equipped with three-phase motors, supplied from the single-phase distribution system through rotating phase-converters. Twelve of these are induction machines and four are synchronous. Passenger trains and light freight trains are operated over the electric zone by steam locomotives.

14. — *Pennsylvania Railroad.*

a) New York and Philadelphia, Pa., and suburban territory, Philadelphia.

(Extension in progress to Washington, D.C.)

Electrification started 1915. (Original terminal electrification at New York started in 1910 with third-rail operation).

Route miles 221. Track miles 697 (now electrified) (Additional under construction — route miles 232, track miles 1082).

Power distribution, single-phase, overhead catenary, 11 000 volts, and direct-current, third-rail, 650 volts.

Locomotives — freight 2, passenger 46, switching 10. Multiple-unit cars — motor-cars 450. (Total including equipment purchased not yet delivered — Locomotives, passenger 104, freight 118 — switching 44; multiple-unit cars — motor cars 494, trailers 44.)

Power is largely purchased — steam and hydro-electric sources. Generated 60 cycles, delivered 25 cycles, three-phase and single-phase from frequency-changers at substations owned and operated by the power companies. The railroad operates single-phase transmission lines at 44 000 and 132 000 volts, and three-phase at 11 000 and 37 500 volts.

This project has grown from the original Philadelphia suburban territory electrification and the initial New York tunnel and terminal operation. The Philadelphia suburban original electrification permitted postponement for about fifteen years of the reconstruction of the Broad Street terminal, which would have been exceedingly expensive. The savings due to the original electrification were thus incidental. Complete electrification of the suburban traffic at Philadelphia has now made available air rights of great value at Broad Street, in the heart of Philadelphia, through the construction of a suburban terminal entirely underground. The « through » electrification between New York and Washington is being accomplished to increase speed of both passenger and freight, to unify operation and avoid duplication, and to obtain general economies. It will be, when it is completed, the most comprehensive electrification in the United States.

b) Suburban territory on Long Island, New York, N.Y.

Electrification started 1905.

Route miles 126. Track miles 363.

Power distribution, direct-current, third-rail, 650 volts.

Locomotives — passenger and freight 16 — switching 2.

Multiple-unit cars — motor-cars 825, trailers 251.

Power is produced and purchased — steam sources. Delivered at 25 cycles, three-phase, and at 60 cycles, three-phase, to synchronous converters and mercury-arc rectifiers, at 29 substations owned and operated by the railroad.

This is a typical suburban electrification entering New York City from the east, through long tunnels under the East River, to a joint terminal with the « through » Pennsylvania Railroad traffic from the west. All the terminal tracks are entirely underground. The advantages of electrification of suburban service are thus combined with those of electric operation in a very congested terminal, and through long tunnels. In fact it may be said that without electric traction the operation as now accomplished would be fundamentally impossible. « Through » trains from the east of Long Island are hauled through the electric zone by electric locomotives , and freight within the limits of New York City is hauled electrically.

c) **Bay Ridge to Fresh Pond Jct., Long Island, New York City.**

Electrification started 1926.

Route miles 12. Track miles 83.

Power distribution, single-phase, overhead catenary, 11 000 volts.

Locomotives — freight 14.

Power normally furnished from the New York, New Haven and Hartford, R.R. system, 25 cycles, single-phase, with mutual standby connection through a motor-generator with the 25-cycle, three-phase supply of the Long Island Division.

This electrification was installed in coordination with the electrification of the New York, New Haven and Hartford Railroad and of the New York Connecting Railroad, and handles freight traffic only. The « trough » freight trains from New Haven operate electrically to the car floats at Bay Ridge whence the cars are ferried accross New York Harbor.

15. — *Reading Company.*

Suburban territory, Philadelphia, Pa.

Electrification started 1931.

Route miles 69. Track miles 161.

Power distribution, single-phase, overhead catenary, 11 000 volts.

Multiple-unit cars (all motor-cars) 70.

Power purchased — steam and hydro-electric sources — delivered 60 cycles, three-phase, to frequency-changers at one substation, owned and operated by the power company.

This is a typical suburban electrification. Steam locomotives operate « through » traffic over the electrified tracks into the terminal. An interesting feature of this installation lies in the fact that the frequency-changers are « outdoor » machines, the auxiliary apparatus, such as metering equipment, etc., being within the foundations. A track laid alongside the substation will enable heavy maintenance by means of a locomotive wrecking crane, thereby doing away with the necessity for installing a crane at the substation.

16. — *Virginian Railway.*

Mullens, West Virginia to Roanoke, Virginia.

Electrification started 1925.

Route miles 135. Track miles 230.

Power distribution, single-phase, overhead catenary, 11 000 volts.

Locomotives — freight 11 (3-cab units), switchers 3.

Power produced — steam source, generated and delivered to railroad transmission system single-phase, 25 cycles. A single-phase mutual standby connection with the Norfolk and Western Railroad has been made.

This is largely a very heavy coal-carrying service, through mountainous country where grades and curves are severe. Electric operation has resulted in great economy due to handling heavier trains at higher speeds than was possible with steam. A number of tunnels are encountered along the route, and electrification has simplified operation through these tunnels. Regeneration is employed on descending grades. About 20 % of the total energy consumed to propel trains eastbound is regenerated. The westbound trains, running empty as they do, do not regenerate a large amount of power. The total regeneration is on the order of 8 % of the total energy required to operate the railroad. The motors are three-phase, with synchronous phase-converters to supply energy from the single-phase distribution circuit.

Mexico.

17. — *Mexican Railways.*

Esperanza to Paso del Macho.

Electrification started 1925.

Route miles 64. Track miles 70.

Power distribution, direct-current, overhead catenary, 3 000 volts.

Locomotives (passenger and freight) 12.

Power purchased — hydro-electric sources delivered 60 cycles, three-phase to motor-generators (three-unit), at two substations owned and operated by the railroad.

This electrification over very heavy grades (up to 4.7 %) was undertaken for general economic reasons and to increase track capacity. Operating expenses were very high, both in labor and material. The steam locomotives burn oil and hydro-electric power is readily available. Regeneration is employed on descending grades. It has been stated that the annual return on capital required for the electrification has been about 26 %.

Cuba.

18. — *Hershey-Cuban Railway.*

Havana to Matanzas and branches.

Electrification started 1920.

Route miles 54. Track miles 111.

Power distribution — direct-current, overhead catenary, 1 200 volts.

Locomotives — freight 11.

Multiple-unit cars — motor-cars 21.

Power produced — steam source. The railroad power plant (oil burning) also supplies commercial power to communities along the route. 60 cycle, three-phase power is supplied to rotary converters (two in series) at three substations owned and operated by the railroad.

This electrification was primarily installed on account of the high cost of oil which is utilized as fuel in Cuba, and the difficulty of obtaining satisfactory operation of steam locomotives with the labor available in Cuba. There was also considerable expense involved in maintaining proper feed-water supply along the route for steam locomotives, especially in dry weather. This trouble was, of course, eliminated by the electrification. The road has very heavy grades, and operation over these was facilitated by electrification.

South America.

Argentine.

19. — *Buenos Ayres Western Railway.*

Buenos Aires and Moreno and (for freight) the city of Buenos Aires.

Electrification started 1923.

Route miles 22. Track miles 82.

Power distribution — direct-current, third-rail, 800 volts (for freight only overhead catenary).

Locomotives — freight 2.

Multiple-unit cars — motor cars 76, trailers 97.

Power produced — steam source, delivered 25 cycles three-phase to rotary converters at four substations, owned and operated by the railroad.

This electrification combines a suburban operation with freight through a long tunnel under the city from Plaza Once to the docks of the port of Buenos Ayres. The electrification was originally necessary on account of growing congestion of traffic. The capacity of the line was increased and service much improved by electrification, which in turn produced increased traffic. The third-rail is of unusual channel design — somewhat like an inverted letter « L » boxed with wood on the top and outside, the contact being on the under side of upper flange.

20. — *Central Argentine Railway.*

Buenos Aires to Tigre West, Tigre East and Villa Ballester and Bancalari.

Electrification started 1916.

Route miles 43. Track miles 113.

Power distribution, direct-current, third-rail. 800 volts.

Multiple unit cars — motor cars 125, trailers 118.

Power produced — steam source, delivered 25 cycles, three-phase to rotary converters at nine substations owned ond operated by the railroad of which four are manual and five automatic.

This is a suburban electrification, originally installed on account of congestion. The capacity of the railroad was increased and service improved by electrification. The standards are similar to those of the Buenos Aires and Western Railroad.

Brazil.

21. — *Paulista Railway (5′ 3″ gauge).*

Jundiahy to Rincao.

Electrification started 1921.

Route miles 204. Track miles 252.

Power distribution, direct current, overhead catenary, 3 000 volts.

Locomotives — passenger 13, freight 27.

Power purchased — hydro-electric sources, with steam auxiliary. Delivered 60 cycles, three-phase, to motor-generators at seven substations, owned and operated by the railroad — one portable substation.

This electrification carries passenger and freight traffic. It was started on account of the scarcity and high cost of coal and of wood largely used as fuel. Water-power is fairly abundant, but it is necessary to supplement it by steam plants. The operation is over heavy mountain grades, and regeneration of power is employed on descending grades. It is said that maintenance of the electric locomotives is about one-third that of steam locomotives displaced and that the saving of fuel has been about three-quarters. The capacity of the line has been considerably increased by electric operation.

Chile.

22. — *Chilean State Railways (5′ 6″ gauge).*

Valparaiso to Los Andes and Santiago.

Electrification started 1923.

Route miles 144. Track miles 236.

Power distribution, direct-current, overhead catenary, 3 000 volts.

Locomotives — passenger 21, freight 15, switching 7.

Power purchased — hydro-electric sources, with steam auxiliary, delivered 50 cycles, three-phase, to motor-generator sets at five substations owned and operated by the railroad.

This electrification carries both passenger and freight service over heavy mountain grades, and through a large number of tunnels. Fuel is scarce and expensive and hydro-electric power available.

Great Britain, Dominions and Colonies.

23. — *London Midland & Scottish Railway.*

a) Suburban territory, London (two separate sections operated jointly with local rapid transit facilities).

Electrification started 1905.

Route miles 45. Track miles 101.

Power distribution, direct-current, third-rail and fourth-rail, 600 volts.

Multiple-unit cars — motor-cars 153, trailers 237.

Power produced and purchased, delivered 50 cycles, three-phase to rotary-converters at eleven substations owned and operated by the railroad.

This electrification is typical of a number of electrical operations about London, in that there is coordination with rapid-transit operation. Steam service for « through » passenger traffic and freight is operated over the electrified tracks. Storage batteries are used to help carry peak loads.

b) Manchester to Holcombe Brook.

Electrification started 1914.

Route miles 14. Track miles 20.

Power distribution, direct-current, third-rail, 1 200 volts.

Multiple unit cars — motor-cars 38, trailers 28.

Power produced — steam sources, delivered 25 cycles, three-phase to rotary converters at two substations.

This electrification employs the only high-voltage third-rail in England. A specially constructed and protected type of rail is used with side contact. The installation was originally 3 600 volts, direct current, with overhead catenary.

c) Manchester to Altrincham (jointly owned with London North Eastern Railway).

Electrification started 1931.

Route miles 10. Track miles 28.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 24, trailers 44.

Power purchased — steam source, delivered 50 cycles three-phase to rotary converters at two substations, one manually operated, the other by remote control.

This project is of interest in that it is the first installation in Great Britain of 1 500-volt, direct-current power distribution for multiple-unit car operation, and the first electrification to be installed since the adoption of that system by the Ministry of Transport as standard. The primary reason for the electrification was highway competition. Scheduled running time between terminals is decreased in spite of the institution of added local stops, and the frequency of train service increased about fifty per cent.

d) Liverpool to Southport, Crossens and Omskirk.

Electrification started 1904.

Route miles 38. Track miles 93.

Power distribution, direct-current, third-rail and fourth-rail, 600 volts.

Power produced — steam source, delivered 25 cycles, three-phase to rotary converters.

This electrification was installed primarily on account of the fact that under steam operation, the capacity of that section of the railroad had been reached. The electrification produced increased traffic and it is understood that the capacity of the line has again been reached and that a revision of the present electrification system is under consideration.

24. — *London & North Eastern Railway.*

a) Newcastle to Tynemouth.

Electrification started 1904.

Route miles 32. Track miles 81.

Power distribution, direct-current, third-rail, 600 volts.

Multiple-unit cars — motor-cars 91, trailers 61.

Locomotives — switchers 2.

Power purchased — steam source, delivered 40 cycles (shortly to be changed to 50 cycles) three-phase, to rotary converters at five substations owned and operated by the power company.

This electrification is essentially for suburban and terminal service, to meet outside competition. Recent highway competition has been successfully met by ten-minute service. Power is available relatively cheaply in this territory, because the power company maintains interconnection with systems of iron and steel plants which utilize large amounts of waste heat for power generation.

b) Shildon-Newport (near Middlesborough).

Electrification started 1915.

Route miles 19. Track miles 45.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Locomotives — freight 10.

Power purchased — steam sources, delivered 40 cycles (shortly to be changed to 50 cycles), three-phase, to rotary converters (two in series) at two substations owned and operated by the power company.

This electrification carries freight, largely coal, from mines to tide-water. The traffic is of high density. Power is relatively cheap because of interconnection between the power company and steel mills which utilize waste heat for power generation. It is of interest that a portion of the electrified route coincides with the route of the first commercial railroad to be operated in England (Stockton to Darlington, 1825).

25. — *Southern Railway.*

Suburban territory, London and to Brighton and Worthing.

Electrification started 1909.

Route miles 307. Track miles 820.

Power distribution, direct-current, third-rail, 650 volts.

Multiple-unit cars — motor-cars 888, trailers 1 119.

Power produced and purchased — delivered 25 cycles and 50 cycles, three-phase, to rectifiers and rotary converters at forty-eight substations of which three are not attended.

This is the largest suburban electrification in the world. More than 16 % of the mileage of the Southern Railway system is electrified. It represents the consolidation of a number of projects operated by railroads now comprising the Southern Railway System. A portion of the present electrified system was originally installed single-phase, but was changed to conform with the rest of the system to obtain unified operation. It is said this electrification by rapid and frequent schedules has brought back to the rails traffic formerly lost to highway competition.

Australia.

26. — *New South Wales Government Railways.*

Sydney and suburbs.

Electrification started 1926.

Route miles 88. Track miles 262.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 307, trailers 295.

Power produced and purchased — delivered 25 cycles, and 50 cycles, to mercury-rectifiers and to rotary converters (some operate singly and some two in series) at thirteen substations.

This is a typical heavy suburban electrification. An interesting item of estimated saving — permissible only with government-owned railroads — has been suggested in connection with saving of time in transit, made possible by electrification. It has been estimated that the saving of passengers' time on account of accelerated service amounts to 20 000 000 passenger-hours per year. At one shilling per passenger-hour, this would amount to £ 1 000 000 per year, which, capitalized, would amount to nearly 80 % of the total cost of electrification.

27. — *Victorian Railways (Government-owned).*

Suburban territory Melbourne.

Electrification started 1919.

Route miles 172. Track miles 439.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 390, trailers 466.

Locomotives — freight 12.

Power produced — steam source, 25 cycles, three-phase, delivered to rotary converters at eighteen substations, of which four are automatic.

This electrification carries a typical suburban traffic. It was originally installed as an alternative to construction of additional tracks to take care of rapidly increasing business. It is said that the Flinders Street Station is the busiest railroad terminal in the world — 2 450 electric trains and 260 steam trains are handled there on a normal day. The increase in traffic since electrification has been noteworthy since much of it is has taken place in spite of keen competition from outside. The annual increase since electrification has been about 11 % as compared with 4 % annually under steam operation. Some freight is handled electrically in the electrified territory, but all « through » passenger traffic is handled by steam. Fuel is relatively expensive in the district, and the saving of fuel is therefore important.

India.

28. — *Bombay, Baroda & Central India Railway.*

Colaba to Borivli (near Bombay).

Electrification started 1928.

Route miles 23. Track miles 75.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 40, trailers 120.

Power purchased, hydro-electric sources, delivered 50 cycles, three-phase, to rotary converters (two in series) at three substations operated by supervisory control.

This electrification was primarily installed to take care of increasing service demands, the capacity of the railroad under steam operation having practically been reached. Coal is expensive and hydro-electric power in the mountains known as the Western Ghats, is abundant.

29. — *Great Indian Peninsula Railway (State Railway of India).*

Suburban territory Bombay, and to Kalyan, Poona and Igatpury (to Bandra over the line of the Bombay, Baroda and Central India Railway).

Electrification started 1925.

Route miles 180. Track miles 570.

Power distribution, direct-current, overhead catenary, 1 500 volts.

Multiple-unit cars — motor-cars 38, trailers 108.

Locomotives — passenger 24, freight 41.

Power purchased — hydro-electric source, delivered 50 cycles, three-phase, to rotary converters at four substations.

This electrification was originally accomplished to handle very heavy suburban service and was subsequently extended across the mountains known as the Western Ghats, to take in operation over heavy grades and through long tunnels. Regeneration is accomplished on descending grades with freight but not with passenger trains. Fuel is expensive and water power abundant. The capacity of the line has been increased.

New Zealand.

30. — *New Zealand Government Railways.*

a) Christchurch to Lyttleton.
Electrified 1929.
Route miles 6. Track miles 15.
Power distribution, direct-current, overhead catenary, 1 500 volts.
Locomotives (passenger and freight) 6.
Power purchased — delivered to rotary converters (single armatures) at one substation.

This electrification includes passenger and freight traffic over heavy grades and through long tunnels.

b) Arthur's Pass to Otiro.
Electrification started 1924.
Route miles 8. Track miles 13.
Power distribution, direct-current, overhead catenary, 1 500 volts.
Locomotives (passenger and freight) 6.
Power produced.

This is a typical tunnel electrification. The tunnel (over five miles long) is said to be the longest in the British Empire. Both passenger and freight traffic are handled electrically.

South Africa.

31. — *South African Railways (3′ 6″ gauge).*

Pietermaritzburg to Glencoe and branches.
Electrification started 1926.
Route miles 170. Track miles 244.
Power distribution, direct-current, overhead catenary, 3 000 volts.
Locomotives (passenger and freight) 95.
Power purchased from Electricity Supply Commission, steam sources, delivered 50 cycles, three-phase to motor generators (three-unit) at eleven substations in addition to one substation supplied direct from the power plant. All are automatic and are owned and operated by the railroad.

Coal is plentiful and cheap in South-Africa. The electrification was installed as an alternative to double-tracking the line. Both passenger and freight traffic are handled electrically. One advantage of electrification has been the elimination of the fire hazard in the grass along the route. Regenerative braking is employed on descending grades. It is of interest to note that in the study for this electrification no estimate was included for fuel economies. Large savings were estimated in locomotive maintenance, depreciation and in operating wages. It is estimated that over 22 000 000 kw.-h. of energy is regenerated annually which would otherwise be absorbed in brake shoes. This is about 18 % of the power used.

Japan.

32. — *Chichibu Railway (3′ 6″ gauge).*

Kumagaya to Magemori.
Electrification started 1922.
Route miles 40. Track miles 50.
Power distribution, direct-current, overhead catenary, 1 200 volts.
Locomotives (passenger and freight) 5.
Multiple-unit cars — motor-cars, trailers 3.
Power purchased — hydro-electric source, delivered to rotary converters (two in series) at two substations.

This electrification carries considerable lime stone and lumber from the mountains.

33. — *Japanese Government Railways (3′ 6″ gauge).*

Tokio and Yokohama suburban territory and main line.
Electrification started 1904.
Route miles 160. Track miles 490.

Power distribution, direct-current, overhead catenary, 600, 1 200, 1 500 volts.

Locomotives — passenger 82, freight 15.

Multiple-unit cars — motor cars 486, trailers 489.

Power purchased and produced — hydroelectric sources, supplemented by steam sources. Delivered mostly 50 cycles, three-phase, to rotary converters and motor-generators at seventeen substations, some manually operated, some remotely controlled, and some automatic.

The Japanese Government has adopted as standard, direct-current, 1 500 volts, and all of its electrified railroads will eventually be operated on that basis. Some of the energy comes from Government-owned plants and some from private plants. The two main reasons for the comprehensive electrification program being carried out in Japan are the shortage of coal and the congestion of traffic over the narrow-gauge railroads. An interesting feature in connection with the power supply lies in the fact that at one of the power plants the turbine facilities may be operated for an output of either 50 cycles or 60 cycles. If 50-cycle output is desired, the speed is 250 r.p.m., while for 60 cycles, it is 300 r.p.m.

APPENDIX B.

Mileage of track electrified or in process of electrification at various nominal voltages in the territory covered in this report. Data summarized from reports of National Electric Light Association, Committee on Steam Railway Electrification, U. S. A.

	Direct current						Alternating current		
COUNTRY.	600	800	1 200	1 500	2 400	3 000	3 300	6 600	11 000
United States	1 272	...	313	154	122	1 108	...	...	3 273
Canada	...	...	...	...	95	...	12	...	...
Cuba	168	...	111	...	...	...	...	...	...
Mexico	19	...	...	...	...	70	...	...	...
Argentine	...	173	...	...	...	...	...	...	...
Bolivia	9	...	...	...	...	...	...	...	...
Brazil	...	...	..	66	...	252	...	...	...
Chile	47	...	...	33	24	260	...	...	...
Venezuela	...	..	...	25	...	...	...	...	...
British Isles	1 105	...	29	80	...	...	...	20	..
Australia	..	...	...	701	...	...	...	...	...
India	...	...	...	688	...	...	...	...	...
South Africa	...	...	..	65	...	309	...	...	...
New Zealand	...	...	...	28	...	...	...	...	...
China	...	...	100	..	...	...	...	...	...
Japan	13	...	142	412	...	...	...	...	...

APPENDIX C.

Report of the Committee on main line railway electrification, Great Britain.

One of the most notable studies of the economies of railway electrification on a large scale in recent years has been that issued by the Committee on Main Line Railway Electrification of Great Britain under the Chairmanship of the Right Hon. Lord Weir of Eastwood. The study has been painstakingly made and is exceedingly comprehensive, although some exceptions, as might be excepted, have been taken to its conclusions. The Committee's assignment made definite mention of the « progress which is being made towards wide-spread availability of high tension electrical energy » in Great Britain. The study is thus based upon close coordination between the national scheme of generation of electrical energy and the railroads. Indeed one of the important items held to justify general electrification in the British Isles is the favorable reaction of the addition of the coordinated railroad load upon commercial power costs.

Opportunity is taken to present a few salient quotations from the summary of the report which it is felt are of interest :

« The main reasons which have led to the adoption of electric haulage in foreign countries, broadly speaking, do not apply in this country, and they have not offered any conclusive guide or assistance in our investigations.

« British railway electrification up to now has been confined to suburban lines, and the results, economic and otherwise, have been favourable.

« The economic success of British suburban electrification is due to the substantial increase in revenue following on the much improved service which an electrified railway can provide.

« Suburban electrification provides no sound comparison of actual operating costs of steam and electric haulage, but it does present certain prima facie considerations in favour of electric haulage for main lines.

« The increased load on the national system to which electrification of the railways would contribute, together with its high load factor, would react most favourably on the cost of the electrical energy produced for all purposes, which the additional transmission network required for railway electrification would do much to accelerate rural electrification throughout the country.

« In the event of a scheme of main line electrification being adopted, the Central Electricity Board should be given statutory power to supply electrical energy direct to the railways for electrification schemes. In addition to this, railway companies should be entitled to utilize, for purely railway purposes, at any point in their systems, supplies of electrical energy obtained from the Board and any other authorized undertakers.

« In any comprehensive scheme of railway electrification the Central Electricity Board should provide the transmission line, build and equip the sub-stations, and supply the energy at the direct-current bus bars of the sub-stations, but the operation and control of the sub-stations should be in the hands of the railway companies.

« Improvements in the fuel economy of steam tractors will take place, but such economy is likely to be counterbalanced by higher capital costs and maintenance charges.

« In considering alternatives to the steam locomotive preference should be given to systems using coal rather than oil as being in the national interest.

« Apart from the direct financial economies of electrification as disclosed in comparative costs of operation, electrification offers important indirect advantages associated with speed, comfort, amenity, improved service, and increase of capacity.

« Leaving aside the financial aspects of the matter, the disadvantages of electrification relate almost entirely to the dependence of the system on centralised sources of electrical energy.

« The main items of haulage cost which can be materially reduced by electrification are locomotive wages and locomotive repairs.

« Unless special conditions obtain, the electrification of small sections of a main line railway system is unlikely to be economically justified on account of the costs of dual working, and the consequent inability to take the fullest advantage of the new capital expended on fixed equipment or haulage units.

« To secure the fullest economic advantage of railway electrification in this country, any scheme adopted should be a comprehensive one preferably comprising all the non-electrified lines, less such branch lines as detailed examination may show to be more economically operated by independent haulage units either steam or oil-electric.

« Assuming that such a scheme is carried out on a comprehensive programme over a period of from 15 to 20 years, on a conservative basis and on the assumption of existing traffic, the new capital involved on the part of the Railways would be approximately £ 261 000 000, and the return on this through the various economies would represent about 7 per cent.

« Apart from the direct return due to these economies other substantial advantages could be realised, the most important being increased revenue from suburban and interurban traffic. On a broad estimate we anticipate that schemes of intensifying suburban working would yield an additional revenue of £ 5 850 000 representing a return of 13 per cent, on the additional capital expenditure of £ 45 000 000 which would be involved.

« In addition to the expenditure under this programme, there would be a further expenditure by the Central Electricity Board and authorized undertakers of approximately £ 80 000 000 in excess of existing programmes, on which these bodies would earn their normal revenue.

« The change over from steam to electric traction will not materially affect the conditions of railway employees other than those in the locomotive grades. Even in the case of these grades we anticipate the adverse effect of the change will be of a limited and temporary character owing to the duration of the programme, together with the probable increase in suburban and other train mileage. The matter, however, is one which should be more closely examined if it should be decided to proceed with the scheme.

« From the point of view of technical development and international competition the value of such a programme of domestic electrification would be most substantial to our national electric manufacturing industry. »

[621. 132.8 & 625 .616]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

12th SESSION (CAIRO, 1933)

QUESTION XIII :

Use of rail motor cars on secondary railway lines.

REPORT No. 1

(Great Britain, Dominions and Colonies, United States of America, China and Japan),

by A. D. J. FORSTER,
Assistant Commissioner, New South Wales Government Railways, Sydney.

In order to obtain information on which to base a report on this question, a questionnaire was circulated to the directorates of railways in the British Empire, United States and Japan. Twenty-six replies were received, of which ten were from the British Empire, fourteen from the United States and two from other countries. A modified copy of the questionnaire together with a summary of the replies received, is appended to this report.

As will be seen, the questionnaire was divided into five broad sections, covering : 1. Organisation, 2. Particulars of cars, 3. Technical features, 4. Technical and economic results and 5. General observations, and for convenience this report will deal with the matter under the same headings.

PART 1. — Organisation.

Track gauge. — Of the railways reporting, one is of 1.676 m. (5 ft. 6 in.) gauge, 17 of 1.435 m. (4 ft. 8 1/2 in.) gauge, 8 of 1.067 m. (3 ft. 6 in.) gauge and one of 1 m. (3 ft. 3 3/8 in.) gauge. A few of the systems operate more than one gauge.

Temperature. — As was to be expected, India experiences the highest maximum and also the highest mean daily summer temperature. On the other hand, winter temperatures in the territory of the East Indian Railway, whilst not reaching extremes, are quite low, so that the range between mean daily temperatures in the summer and winter is great.

Extremes of winter temperature are met with in North America, particularly in the northerly portion. It is important to keep these differences of climate in mind, for they must indubitably have an influence on structural features of the cars and possibly on operating methods also.

Topographical features. — On the whole, it cannot be said that gradients on the sections operated by rail motors are severe. With some notable exceptions grades in excess of 2 % are short, usually from one quarter to one half mile. The principal exceptions are :

United States 6.4 miles of 3.3 % grade on the Chesapeake and Ohio R. R.; 9.2 miles of 2.75 % grade on the Baltimore and Ohio R. R.; 10.6 miles on an average grade of 2.3 % on the Great Northern R. R., and 10.7 miles of 2.2 % grade on the Northern Pacific R. R.

Canada : 3 miles of 2 % grade on the Canadian National Railways.

Africa : 4.2 miles on an average grade of 2.1 % on the South African Railways.

Australia : 3 miles of 2.5 % grade on the Tasmanian Government Railways and 8.4 miles of 2.2 % grade on the New South Wales Government Railways.

Curves, on the other hand, are surprisingly sharp, particularly on the standard gauge tracks in North America. It is true that a number of these sharp curves occur within yard limits or at junction points, yet numerous examples occur on main lines, the sharpest being curves of 249 ft. radius (23°) on the Canadian National Railways.

Character of services. — Whilst it is probably true that the majority of services run by rail motor are of a local character, there is a tendency, particularly noticeable on those systems operating numerous cars, for the length of individual runs to be extended, and several instances are quoted of runs of 300 miles and over being operated by rail motors. On these long runs the stops are relatively few, the distance between stops usually exceeding 6 miles, but the schedule speed seldom exceeds 30 miles per hour.

With reference to schedule speeds, it is noticeable that the average schedule speed is consistently of the order of 25 m. p. h. and this figure may be taken as a universal standard.

General considerations. — Whilst not general, it is common practice to inform the public, per medium of the time tables, which trips are operated by rail motors. No instance is definitely recorded where bookings by these trips are restricted to the accommodation available, but, where the traffic offering is beyond the capacity of the rail motor and trailers, it is customary to use a steam train in lieu.

With the exception of purely local services, rail motors are subject to predetermined connections with other trains and in this regard are treated in exactly the same manner as the steam services which they have superseded. Very few instances of interpolated trips are given, rail motors having in most cases superseded steam trains and generally steam passenger trains. In those cases where mixed trains have been displaced it is usual for steam mileage to be reduced, as generally an occasional freight or mixed train is sufficient to handle the freight business. Express freight and livestock traffic has not been affected.

The principal reason for the adoption of rail motors has been the economic advantage, and the same reason is influencing consideration of the extended use of these cars on main lines, though the desire to improve facilities and to counter road competition is also being given weight. Motor cars have been used to a very minor extent on main line services preceding or following express passenger trains for the purpose of reducing the number of stops to be made by the latter. Instances are given of the use of rail motors on experimental service, in most cases with unsatisfactory results.

It is not customary to restrict rail motors to services which do not operate on Sundays. Naturally, however, many services are of this character and advantage is usually taken of any days out of service for carrying out maintenance work. The provision of spare cars to replace motors withdrawn either for running repairs or for general overhaul is not general; the reason for this is probably the facility with which a steam train can be provided.

In North America the use of single ended cars is practically universal, necessitating turning of the cars at terminal points. This feature is rather surprising in view of the predominance of electric transmission, which renders the provision of duplicate controls a relatively simple matter. A tendency is apparent, however, towards the provision of double end control in modern construction. The reason for the adoption of the single end car in America cannot be assigned. Elsewhere double ended cars are the rule. In no case is provision made for multiple unit control.

Maintenance of rail motors is usually carried out in locomotive sheds, though in some cases the rail motor portion is partitioned off. Where a considerable number of cars is operated it is usual to employ a special, or specially trained staff for maintenance work. The same observation can be made regarding the employment, or otherwise, of special supervising officers, it being found necessary or advisable to do so whenever several motor cars are in use.

Joint control of the operating staff by the mechanical and transportation departments is less common than complete control by the latter section. The practice in this matter is probably that ruling in steam operation and has no especial significance. Locomotive engineers are generally utilised as drivers, though one road reporting employs mechanics for driving and maintenance. Conductors, brakemen, etc., are also employed, but no general rule is observable for fixing the numbers. It may be stated, however, that steam driven rail motors require the provision of a fireman in addition to the driver, whereas other types of car are satisfactorily operated with a driver alone.

Methods of clearing the track in the event of a failure en route follow steam practice. In one or two cases portable telephones are carried to facilitate communication in the event of assistance being required.

The supply of spare parts is governed by the facility with which replacements may be obtained from the manufacturers. In North America complete engines are not usually kept, and the stock of spare parts is at a minimum. In Australia, however, and other parts of the British Empire more extensive provision must be made on account of the time which must necessarily elapse owing to the need for importation.

PART 2. — Particulars of cars.

In dealing with this section it will obviously be impracticable in view of the multitude of types to list particulars of all cars in operation. As the object of this enquiry is to obtain information on latest developments all that will be attempted is to comment on the latest types of construction. Similarly, the attached summary of replies will only deal with the newest vehicle for each of the railways reporting. This will involve some slight departure from the form of questionnaire actually circulated, but the variation is not serious.

Types of car. — Consideration of this summary at once discloses certain pronounced tendencies. Firstly, in North America, petrol = (or oil) electric cars may be said to be standard for more recent construction; elsewhere steam cars are more common. Secondly, in North America engines of 200 H. P. and over are general, with a pronounced trend towards dual unit sets of a total horse power of 400 to 600. Elsewhere engines of 100 H. P. are the rule. Thirdly, in North America cars are becoming standardized with a body length between 70 feet and 75 feet, with a leaning towards all-steel construction, the corresponding light weight varying from 100 000 lb. for single engined composite construction cars, to 160 000 lb. for twin engined all-steel construction cars. Elsewhere the usual body length is around 50 feet (excepting articulated cars), the light weight varying from 30 000 lb. to 65 000 lb.

The reasons for these differences can be deduced to a degree. In the first place, cost and availability of fuel must have an important bearing in determining the type and power of the prime mover. Secondly, the volume of business, the type of passenger and the class of accommodation provided by other rail and road transport must influence the size and weight of the car, and consequently the engine power. As pointed out previously there are no pronounced differences in the physical characteristics of the terrain served.

Other features. — There are certain features, largely consequential on the tendencies above noticed, which are deserving of mention. The number of driven axles is dependent on the power available, being frequently one with engines of 100 H. P., and always two with engines up to 300 H. P., and four with engines of 400 H. P. and over.

Furthermore, the amount of passenger accommodation provided in the motor cars decreases as the power increases, and many cases are quoted where the whole of the accommodation on the motor car is allotted for the carriage of baggage and mails. The baggage space in the high powered cars is invariably located next to the engine compartment. It is apparent that the noise and vibration inseparable from the operation of the prime movers must seriously affect the comfort of passengers. The Canadian National Railways have adopted articulated construction for their 8-cylinder engined car, thereby, no doubt, largely improving matters from the point of view of passenger comfort.

Power brakes are general, being usually vacuum operated on steam cars, and air pressure operated on other types. With few exceptions brakes are provided on all wheels, the percentage of brake power averaging 90 % of the light weight of the car.

Heating facilities are provided on North American railways and in Japan and Korea, the system adopted being hot water from a separate heater in America and jacket water or exhaust heating in the other places mentioned.

Electric lighting, supplemented with oil marker lights in some cases, is standard, power being provided from the exciter or a separate unit on cars with electric transmission, and from an axle driven generator in other cases.

Standard couplers and draft gear are not usually fitted, though generally the couplers are of standard contour and will couple up with the regular standard.

In only a few cases is any limitation placed on the weight of rail motors by the condition of the track. Even in those cases where the axle load is limited to 10 to 13 tons (22 400 lb. to 29 120 lb.) the limitation cannot be as serious for a rail car as it would be for a steam locomotive.

PART 3. — Technical.

In preparing the summary of replies to this section it has been found necessary to deal only with those cars referred to in the summary of Part 2.

Boilers. — All the steam cars listed are either Sentinel-Cammell or Clayton cars, and the equipment is standard for the firms concerned. As information thereon is readily available no detailed description will be attempted in this report. In all cases quoted the boilers are coal-fired.

Prime movers. — Steam engines are single-acting reversible engines, either of two or six cylinders, using medium pressure (300 lb. sq. in.) superheated steam.

Internal combustion engines are of two types, spark ignition and compression ignition, the former predominating. In construction they are quite conventional, the spark ignition type being 6-cylinder engines fitted with dual ignition for powers of 100 H. P. and upwards, and having an operating speed generally about 1 200 r. p. m. Fuel is either gasoline (petrol) with a distillation range usually between 100° F. and 400° F. though in the case of the Southern Pacific Railroad provision was made in the purchase specification that the engines should run on distillate if required, and this type of fuel is apparently largely used by this company.

Two examples of compression-ignition engines are listed in the summary, operated by the Canadian National Railways and the Great Northern Railroad. The former company has many cars of this type with either 4-cylinder, 6-cylinder or 8-cylinder engines. It is the 8-cylinder cars that are listed, though the features of the engines are in general common to the 4 and 6-cylinder engines also. The Great Northern Railroad uses a 6-cylinder engine, as does also the Reading Company, which company operates two oil-electric vehicles, particulars of which are not featured in the summary. Solid injection is used in the compression-ignition engines, the fuel oil having a gravity of about 0.88, with a distillation range starting at about 400° F. The operating speed is 700 to 800 r. p. m.

Lubrication is provided in all cases by pressure feed to the enclosed crank shafts, etc., and in the case of the steam engines the cylinders are lubricated through hydrostatic lubricators.

Fuel and oil strainers are common though not general, but air cleaners are the exception rather than the rule.

Transmission—Mechanical.— Clutches are predominantly of the multiple disc, dry plate type. Gear boxes are in general of the sliding gear type with four forward speeds, and no reverse, the reverse arrangements being associated with the final drive. An exception must be noted in the case of the South African Railways. These cars are fitted with two standard motor car engines and gear boxes (3 speeds forward and reverse), each engine having an independent transmission as far as a lay shaft. The two lay shafts drive the car axle through silent chains. Each engine is independently controlled, and reverse running is only used in shunting movements.

Control arrangements in the case of other mechanical drive cars is by means of the usual clutch and acceleration pedals and gate change gear lever and a separate reversing lever for the final drive, the controls being operable from either end of the car.

Generators. — Electric transmission. — Generators are directly connected to the prime mover, frequently through a flexible coupling. Voltage ranges from 500 to 700, the current rating of the generator of course depending on the engine power. Generator field winding may be shunt or compound wound, but the field is always separately excited. Whilst in many cases the exciter is driven by the main engine, a pronounced tendency is apparent to provide an exciter driven by a separate prime mover. There is much to be said in favour of this development. Batteries are usually charged from the exciter, naturally when the generator is not delivering power. With a separate unit, therefore, the main engine can be shut down, when the car is standing by, whilst battery charging is proceeding normally from the exciter unit. Furthermore, the demand on the battery is much reduced in starting the main engine (which is frequently done electrically through the generator) and for driving auxiliaries such as fans and brake compressor.

Motors. — Motors follow normal railway practice, being of the axle-hung, nose-suspended type with spur or helical gears. Common gear ratios are 57 : 18 and 52 : 19.

Control. — Apart from motor connection alteration, control is by variation of generator voltage, usually arranged as a combination of engine speed and excitation variation; rheostats are not required for the main circuit. There are two main methods of controlling the excitation; in one the exciter is differentially wound so that the main current reduces exciter voltage, and therefore main generator voltage, as the load increases; the other, known as torque control, in one form consists of a small d. c. motor the field of which is connected in series with the exciter field, whilst the armature is shunted across the commutating field winding of the main generator. The armature only moves sufficiently to open or close contacts, thereby varying the generator field according to load variations. The object of either system of control is to prevent overloading the prime mover, and the car is entirely managed through the engine throttle. Other different systems of control are likewise in use.

Auxiliaries. — Engine starting on gas electric vehicles is frequently managed by arranging to use either the main generator or exciter as a motor. This is supplemented in some cases by air starters or by starter motors. On gas mechanical vehicles starter motors, supplemented by hand starting, are the rule. Steam engines, of course, need no special starting arrangements.

Lighting is provided from batteries charged either from the electrical system in cars with electric transmission, or from axle driven dynamos in mechanical and steam cars.

Compressed air for brakes is supplied by motor-driven compressors on gas-electric cars and by engine driven compressors on gas-mechanical cars, which steam vehicles usually adopt vacuum braking, vacuum being maintained by steam ejector.

Fuel supplies. — The quantity of fuel carried on the cars varies widely; steam cars carry sufficient for 100 to 150 miles, but internal combustion engine cars have a radius of action varying from 200 to as much as 800 miles.

Information was sought as to methods adopted for supplying fuel to cars, but the question was apparently not understood as few replies were received. The Canadian National Railways supply fuel oil in barrels from which it is pumped by hand pump (located on the car) to the car tanks. Elsewhere it can be assumed that fuel is supplied by ground pumps from underground tanks. Liquid fuel is supplied only at depots or terminal points, en route supplies not being required. Coal is supplied from the usual locomotive facilities.

Safety precautions. — Chemical extinguishers are standard equipment, the number and capacity varying somewhat. The usual type is the tetrachloride extinguisher, but foamite and carbon dioxide are also used.

No other special arrangements are customary; in South Africa and New South Wales portable telephones are carried to facilitate communication in emergencies, and the latter system likewise carries a manual tricycle for the same purpose.

PART 4. — **Technical and economical results.**

In the summary dealing with this section an attempt is made to present a picture for the services as a whole and not for particular types of car. This principle is departed from in certain cases, however, where useful comparisons may be drawn between different types of cars operated by a particular railway system.

One other point should be mentioned; discrepancies are apparent in certain cases in the replies given to questions 2 and 3, Part IV, and similar information deduced from the data suplied in connection with Part I. These discrepancies are probably due to slight differences in the methods adopted in deducing results. Thus, in estimating schedule speeds from time tables supplied, your reporter has in all cases included time taken in ordinary station stops, but has excluded waiting time. Others may have reckoned schedule speeds from running times only, excluding both stopping time and waiting time.

A few further words of explanation regarding this summary should be made. In the replies to Question 2, total running cost per rail motor mile, interest charges have been subtracted whenever it was known that they had originally been included and when the amount was known, but it is possible that interest charges are still included in some of the figures quoted in the summary.

No attempt has been made to convert dollar (American) currency into sterling, as it was considered that this was sufficiently familiar to all to render the conversion unnecessary. Other less familiar currencies have been converted, the rates used being quoted in the summary itself. Weights, measures and lengths have in all cases been converted to British standards.

Services. — The type of service is predominantly branch line, followed in order of importance by main line services. As mentioned previously schedule speeds are fairly uniform, ranging round 25 m. p. h., but average daily mileages vary rather widely.

Fuel consumption. — For internal combustion engines the performance naturally varies with the type of car. With mechanical transmission the extreme range is from 2.76 to 10 miles per gallon (Imperial), with by far the greater number between the limits of 5 and 8 miles per gallon. All these cars use petrol (gasoline). With electric transmission, cars using petrol (gasoline) give figures varying from 1.16 to 2.88 miles per gallon (Imperial), the greater number giving from 1.8 to 2.0 miles per gallon. Oil fuel figures vary from 2.0 to 4.2 miles per gallon (Imperial). The highest figure in this case is for the 4-cylinder engined cars of the Canadian National Railways, but the average for all oil-electric cars on this railway would probably be about 3.5 miles per gallon.

Lubricating oil consumption figures vary very widely, but it is not too much to say that a figure of 100 miles per gallon (Imperial) should be realisable. It is possible that the wide variation shown may be due to the inclusion in some cases of car oil with engine oil when calculating the consumption.

Prices of fuel. — The variation in price of gasoline (petrol) is surprising. In North America where some degree of uniformity might have been expected prices vary from 6.6 to 16.6 cents in the United States, to 20.5 cents in Canada, in each case the Imperial gallon being the unit. In the other countries reporting the range is between 8.5 d. (17 cents) and 24 d. (48 cents) the highest prices being paid in Australia.

Fuel oil prices, on the other hand, are fairly uniform, ranging from 4.56 to 5.8 cents per Imperial gallon.

Coal prices are difficult to compare owing to quality variations. Unfortunately, information regarding calorific value was not supplied in most cases, so that it is not possible to make a comparison on the basis of British thermal units.

Lubricating oil does not exhibit the wide variation noted above for petrol, and suitable oil may be obtained in any part of the world at prices between 60 and 80 cents (2 sh. 6 d. and 3 sh. 4 d.). In two cases the price quoted for oil is so low that it is assumed some mistake has been made.

Labour rates and conditions. — In North America the standard rates for drivers vary between $ 6.60 and $ 7.50, this rate usually being paid for a turn of 100 miles or less, mileages over 100 being paid for pro rata. Conductors are paid from $ 6.70 to $ 7.50 usually for 150 miles or less. Baggagemen and brakemen usually receive about 75 % of conductors rates. Mechanics uniformly receive $ 6.48 per day of eight hours.

In Australia and New Zealand drivers receive between 17 and 21 sh. per day, guards between 13 and 18 sh. per day and mechanics 15 sh. 6 d. and 19 sh. 6 d. per day. Hours are usually 48 per week, but in New South Wales are 44 per week, the running staff working these hours in six days and the shop staff in five days.

On the South African Railways the rates are closely similar to those quoted about for Australia, but elsewhere in Africa and the East the rates are so extremely variable that no useful comparison can be drawn.

Capital costs. — No useful purpose would be served by attempting to compare cost prices of the cars. The most that need be said in this connection is that petrol-mechanical cars are in general the cheapest with steam vehicles slightly dearer. Petrol-electric cars are much more expensive and oil-electric the dearest of all, the difference between these last two types being of the order of 12 %.

Depreciation may be reckoned either at an inclusive rate on the whole equipment or at different rates on the machinery and the car body. In the former case the rates allowed vary between 3 1/2 % and 12 %; in the latter case rates as high as 20 % are allowed on the machinery, a more usual figure being 10 %, whilst on the car body the allowance is between 3 % and 5 %.

Operating costs. — The figures given in this connection form interesting reading. Probably the most useful method of dealing with the figures is to consider the distribution of costs on a percentage basis, rather than on a monetary basis. This method gives for North America : fuel 15.2 %, stores 6.3 %, crew's wages 49.1 % and repairs 29.4 %. For the remaining reporting systems the results are : fuel 31.2 %, stores 1.6 %, crew's wages 36.1 % and repairs 31.1 %. The figures quoted for operating cost are in general derived from a year's operation after a number of years' experience.

It is the usual custom to charge overhaul costs as they accrue and not to make an allowance per mile, based on experience, to cover this item.

The cost of special superintendence is usually included in general superintendence, and is not charged against rail motor operation.

Total cost and revenue. — Total costs per rail motor mile range between 23 and 79 cents; the latter figure is the total cost for the two large oil electric cars of the Canadian National Railways, the remaining cars costing very considerably less. On the majority of systems, however, total costs fall between 35 and 50 cents.

Many systems do not separate rail motor revenue from general revenue. Where figures are available it is worthy of note that the revenue is seldom sufficient to cover the total costs of the rail motors, and this fact is a striking commentary on the reason for the adoption and extension of rail motor services, namely the desire for economy.

Costs : Rail motor versus steam. — It is possible to get a direct comparison of rail motor costs and costs of the displaced steam service in only a few cases. In North America the ratio of costs in the four cases in which the comparison can be made is so uniform that it may be taken as typical for the rest of this continent; the average figure for these four cases is 0.44, and an almost identical figure is obtained for the New South

Wales Railways. The individual ratios are given below :

Name of railways.	Ratio-Rail motor costs : steam co ts.
Baltimore and Ohio	0.43
Great Northern.	0.40
Missouri, Kansas, Texas	0.50
Reading Company.	0.44
Federated Malay States	0.58
East Indian	0.90
New Zealand Government	0.66
New South Wales Government	0.43

PART 5. — General observations.

Generally speaking, satisfaction is expressed with present equipment. Naturally when rail motors were first introduced, mistakes were made in many directions, ~~but development~~ has been rapid and service requirements are now better understood. It is not suggested that finality has been reached; indeed a glance at the summary of replies will quickly dispel any such idea. The principal disability to date has been lack of power.

Substituted steam trains are used on occasions, either on account of heavy loading due to holidays or special events, or at peak loading periods on suburban services, or to release the motor car for necessary repairs. The influence of limited power is evident in this connection, though it must not be overlooked that with steam facilities available, the provision of more or more powerful rail motors may not be economically justifiable merely to meet occasional demands.

In North America one class only is the rule, but elsewhere two classes are provided. No change is contemplated in this connection, and indeed in those countries where a mixed European and native population has to be catered for, it is difficult to see how the provision of two classes could be avoided.

Difficulties with maintenance have been of a minor nature, at all events with modern cars and trained staff. It seems to be essential, if trouble is to be avoided, to keep rail motor cars away from the fumes from locomotives in the sheds.

Reasons for adoption. — Rail motor operation was adopted preeminently by reason of the need for economy in face of falling business. Searching further for the cause of the decline in business it is found in the rapid extension of road motor competition. It is apparent that rail motor operation has justified itself in regard to reduction of operating costs, but it is open to question whether it has succeeded in attracting lost business back to the railways. Responsible authorities consider that its possibilities in that direction have not been exhausted, and this angle of the question is obviously engaging their attention when considering extension of services.

Economy per se is not the yardstick which is being used at the present, but the advantages to be reaped by improving services at reasonable cost. Although very few motors are at present under construction the reason is definitely financial stringency, and not lack of confidence on the part of the operators.

Probable trend of development. — Apart from four systems who definitely report against the extension of rail motor service, there is a striking unanimity in the opinion expressed that development will be in the direction of train operation. A corollary of this is, of course, the provision of more powerful cars, and this would seem to call for the adoption of electric transmission.

Mention was made when dealing with Part 2 of the evident tendency towards removing passengers from the vicinity of the engine compartment; it is only a step from this to making the motor car a power unit only, and indeed this step would seem to be a necessary consequence of the development of higher powers. A further step, and one which has already been taken, is to make the power unit into a mobile power house supplying energy to the other vehicles on the train. This arrangement has obvious advantages over locomotive operation as regards adhesion, track stresses and the like, but it has equally obvious disadvantages, not the least of which is the matter of cost, and it is as yet too early to say whether the experiment will succeed or be doomed to extinction.

Granted, then, that more powerful cars will appear, and that electrical transmission will be used, it remains to consider the type of prime mover that will be adopted. As regards steam, a little consideration will show that the trend outlined above, when applied to steam operation, leads back directly to the steam locomotive. Coming back, therefore, to the internal combustion engine, the choice lies between the spark ignition type and the compression ignition engine type. The Canadian National Railways declare in favour of the latter type, quoting sound reasons in support, and have certainly backed their opinion in practice. On the other hand American railways have not shown the same inclination to favour this type of engine, the underlying reason probably being, as stated by the Great Northern Railroad, that petrol prices during the last couple of years in the United States were so favourable as to afford no justification for the higher capital expenditure involved in the purchase of compression-ignition engines. There can be no doubt that weight, cost and lack of experience have militated against the extended use of this type. It must be left to the future to show whether advances in design and manufacturing methods and materials can overcome these handicaps, and whether the price advantage possessed by fuel oil will be maintained.

In conclusion, I desire to record my appreciation to the various Railway Administrations for the great amount of work each has done in preparing the mass of information submitted to enable the preparation of this paper; also, I desire to express my thanks to Mr. E. E. Lucy, Chief Mechanical Engineer of the New South Wales Government Railways, and to Mr. R. A. Holloway, of his staff, for the assistance rendered in the preparation of the report.

APPENDICES.

Questionnaire and summary of replies received.

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PART I.

1. *Name of railway*	Baltimore and Ohio.	Boston and Maine.
Gauge	4' 8 1/2".	4' 8 1/2".
1	2	3
2. *Temperature conditions of country :*		
a) *Max. Summer temperature*	106° F.	105° F.
b) *Min. Winter temperature.*	—27° F.	—40° F.
c) *Mean Summer temperature for one day.*	77° F.	85° F.
d) *Mean Winter temperature for one day.*	28° F.	25° F.
3. a) *Number of services.*	18	21
b) *Shortest run* — miles.	6	1.5
c) *Longest run* — miles	154	86.5
d) *Total daily mileage — all cars*	3 453	2 827
e) *Average daily mileage per car.*	181	118
4. a) *Average distance between stops,* miles.	3.2	2.4
b) *Steepest grade %*	2.75 % (9.2 miles).	2.49 % (800 ft.).
c) *Longest grade* — miles	13.7 (1.42 % av.).	3.0 (1.2 % av.).
d) *Sharpest curve* — feet radius	...	318
e) *Average speed* — m. p. h.	26.0	24.9
5. *Weight of rail motor (R.M.)* — lb. Min.	20 150	29 000*
Max.	162 200	112 000
Aver.	97 380	83 500
Weight of trailer — lb. Min.	52 500	39 800
Max.	98 500	71 900
Aver.	80 600	58 000
Average weight of train — lb.	173 740	130 500
Maximum weight of train — lb.	359 200	168 300
6. *From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table, and effected by means of rail motor cars ?*	Yes.	No.
Are they considered as trains having limited seating accommodation ?		
In the contrary case, what steps are taken to deal with an unusual rush of passengers ?	Relief car.	Steam train.
7. *Are the journeys operated by rail motor cars (R.M.) subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection ?*	50 %. Others exclusively local.	Yes.
8. *Is your programme for use of R.M. cars on secondary lines limited to certain extra services interpolated between pre-existing services worked by steam locomotives ?*	Replace steam.	Replace steam.

* Light weights only.

rganisation.

Central of Georgia. 4' 8 1/2". 4	Chesapeake and Ohio. 4' 8 1/2". 5	Great Northern. 4' 8 1/2". 6	Gulf Coast and Internat. Gt. Northern. 4' 8 1/2". 7
98° F.	108° F.	110° F.	98° F.
20° F.	—2° F.	20° F.	28° F.
85° F.	80° F.	67.4° F.	90° F.
40° F.	30° F.	27.7° F.	38° F.
1	9	30	2
16.5	6.6	8	44.2
...	270.8	305	61.5
99	1 572	8 348	211.4
99	157	239	106
...	4.2	5.9	4.4
1.54 % (800 ft.).	3.3 % (6.4 miles).	3.0 % (3 160 ft.).	1.34 % (1 900 ft.).
0.6 (0.87 %).	6.4 (3.3 %).	10.6 (2.3 % av.). 15.7 (1.0 % av.).	4.5 (0.88 % av.).
1 146	251	382	1 432
28	24.8	25.8	20.8
32 000*	31 200*	90 000	...
...	130 000	165 180	...
...	90 480	128 690	...
...	86 000	82 000	...
...	...	213 000	...
...	86 000	118 240	...
...	142 100	246 930	...
32 000	216 000	486 640	...
Yes.	Yes.	Yes.	Yes.
Steam train.	Steam train.	Trailer added or steam train used.	...
Yes.	Yes.	Yes.	Exclusively local.
Replace steam.	Replace steam.	Replace steam.	Replace steam.

1. *Name of railway.*	**Baltimore and Ohio.**	**Boston and Maine.**
Gauge.	4' 8 1/2".	4' 8 1/2".
1	2	3
Have you used R.M. cars to cover complete passenger service on some branch or small line?	Yes.	Yes.
Treatment of freight traffic when mixed trains are replaced.	Does not arise.	None replaced.
9. *Does your service programme comprise an extended use of R.M. cars on main lines?*	No.	Some used at present.
If so, what would be essentially your object?	...	To reduce expenditure.
Have stopping services on main lines, before or after express train, been tried?	No.	...
10. *Have you considered using R.M. cars to establish, at moderate cost, temporary experimental communications, to find out passenger movement, with a view to transferring them, after certain experimental period and in case of good results, to loco.-hauled trains or doing away with them in contrary case? Have you any example?*	Yes, between Harper's Ferry and Strasburg, with poor results.	Yes, between Boston and Bedford. Result unsatisfactory.
11. *Have you assigned, for preference, R.M. cars to certain local runs worked on Sundays and holidays?*	No.	No, but many do not run Sundays.
Are days out of service used for washing and maintenance of cars, so as to work service with smaller number of reserve R.M. cars?	No.	No.
12. *Are reserve cars available locally to provide relief for purpose of carrying out running repairs or the like?*	No.	Not in general.
13. *Are reserve cars available generally to replace vehicles withdrawn for general overhaul?*	No.	Yes.
14. *For each type of R.M. car on your system, please state:*		
a) *Number at present existing;*	19	24
b) *Date of (I) oldest, (II) newest;*	(1) 1923, (II) 1928.	(I) 1924, (II) 1926.
c) *Number effectively used daily;*	19	22
d) *Number out for repairs, etc.;*	0	[illegible]
e) *Annual average mileage per unit.*	47 500	33 300
15. *For R.M. cars with single compartment for driver at one end, please say if at end of run R.M. car is always turned on a turntable.*	No.	Yes, on turntable or wye.

*Based on 93 % availability.

Central of Georgia 4' 8 1/2''. 4	Chesapeake and Ohio. 4' 8 1/2''. 5	Great Northern. 4' 8 1/2''. 6	Gulf Coast and Internat. Gt. Northern. 4' 8 1/2''. 7
Yes.	Yes.	Yes.	Yes.
Freight train instead of mixed.	None replaced.	Bi or tri-weekly freight instead of daily mixed.	No change in freight service.
No.	No.	Some used at present.	No.
...	...	To reduce expenditure.	...
No.	No.	Yes, to reduce number of stops for through trains.	No.
No.	No.	No.	No.
No.	No, but many do not run Sundays.	No.	No.
...	Yes.	Yes.	...
No.	No.	No.	No.
No.	No.	No.	Yes.
1	10	35	8
(I) 1928, (II) —.	(I) 1920, (II) 1929.	(I) 1925, (II) 1930.	(I) 1910, (II) 1926.
1	10	30	8 (?)
0	0	5	4 (?)
29 500	43 150*	62 600	38 500 (?)
Yes, on turntable or wye.	Wherever possible.	Yes, on turntable or wye.	Yes.

1. *Name of railway* . . . . *Gauge* 1	**Baltimore and Ohio.** 4' 8 1/2''. 2	**Boston and Maine.** 4' 8 1/2''. 3
In contrary case, what is the maximum speed permissible for reverse running ?	Same as when running cab first.	Single car, 45 m. p. h.
On shuttle services, is propelling of trailers permitted, to avoid shunting ?	Yes.	Yes, in one case two trailers.
If so, what is maximum speed allowed ?	15 m. p. h.	Reasonable speed.
16. *Do your R.M. cars use locomotive sheds for stabling and maintenance, or have separate sheds been provided ?*	Loco. sheds. Special stalls assigned.	Loco. sheds partitioned off by fire-wall.
Are they looked after by locomotive staff or have you a specialist staff ?	Loco. staff.	Special staff.
Are cars stabled under cover, or in the open ?	Generally in open.	Under cover.
17. *Is operating staff provided and controlled wholly by mechanical department, transportation department, or partly by each department ?*	Jointly.	Jointly.
18. *State the number of men used for driving. What branch ? State number of men used in addition to the above mentioned driving staff, giving the department of service to which they belong :*	One man. Mechanical.	One engineer. Mechanical.
a) For R.M. car running alone;	3 men on main lines	Conductor.
b) *For motor car hauling one or more trailers.*	ditto.	Conductor and fireman.
Any special points governing the number ?	Transportation. Traffic conditions govern.	Transportation.
19. *In the event of failure en route, what special provision, if any, is made for clearing the section ?*	Same as for steam.	Same as for steam.
20. *Is special staff employed on the supervision or superintendence of R.M. operation ? Please give an outline of the organisation and duties of such staff.*	No.	Supervisor of R. Ms. Asst. » » Inspector » Road foreman »
21. *To facilitate maintenance, do you provide spare engines and other parts ? If so, to what extent ? How are such spare parts controlled and used ?*	Yes, spare engine and electrical parts at central depot.	No complete engines. Spare generators, fan and traction motors, cyl. heads and the like at central point.

Central of Georgia 4' 8 1/2''. 4	Chesapeake and Ohio. 4' 8 1/2''. 5	Great Northern. 4' 8 1/2''. 6	Gulf Coast and Internat. Gt. Northern. 4' 8 1/2''. 7
...	20 m. p. h.	...	...
...	Between Hammond and Griffith trailer is propelled.	...	...
...	20 m. p. h.	...	...
No shelter.	Loco. sheds.	Loco. sheds.	Loco. sheds.
Loco. staff.	Loco. staff.	Loco. staff.	Special staff.
In open.	In open	Majority under cover.	Both.
Jointly.	Transportation.	Jointly.	Jointly.
One man. Mechanical.	One man (loco. engr.).	One man. Mechanical	One man. Mechanical.
Conductor.	Gas-mech. One man Gas-elec. Two men.	One man.	...
...	ditto.	Two men.	...
Transportation.	Independent of whether or not trailer is hauled.	Transportation. Number of cars.	...
Same as for steam.	Same as for steam.	Same as for steam.	Same as for steam.
No.	R. M. supervisor (under elec. engr. who reports to Supt. of motive power).	Motor equipt. engr. Electrical engr. 3 motor mechanics and electricians.	No.
No. Ordered as needed.	Few spare parts; before shopping, list is made out and parts ordered from suppliers.	No engines but spare motors at main point. Few small spares at running points.	Yes.

1. *Name of railway.*	**Missouri-Pacific.**	**Missouri-Kansas-Texas.**
Gauge	4' 8 1/2".	4' 8 1/2".
1	8	9
2. *Temperature conditions of country :*		
a) *Max. Summer temperature*	108° F.	106° F.
b) *Min. Winter temperature.*	—13° F.	—20° F.
c) *Mean Summer temperature for one day.*	75.5° F.	80° F.
d) *Mean Winter temperature for one day.*	32.3° F.	40° F.
3. a) *Number of services.*	16	2
b) *Shortest run* — miles.	30	36.7
c) *Longest run* — miles	321	54.1
d) *Total daily mileage — all cars*	3 040	255
e) *Average daily mileage per car.*	169	127.5
4. a) *Average distance between stops*, miles.	...	3.6
b) *Steepest grade %*	2.06 %	1.1 % (4 000 ft.).
c) *Longest grade* — miles	...	2.36 (0.92 % av.).
d) *Sharpest curve* — feet radius	...	955
e) *Average speed* — m. p. h.	...	26.6
5. *Weight of rail motor (R.M.)* — lb. Min.	36 240	70 000
Max.	94 600	97 720
Aver.	71 900	83 860
Weight of trailer — lb. Min.	...	...
Max.	77 660	...
Aver.	...	...
Average weight of train — lb.	110 730	83 860
Maximum weight of train — lb.	172 260	97 720
6. *From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table, and effected by means of rail motor cars ?*	Yes.	Yes.
Are they considered as trains having limited seating accommodation ?		
In the contrary case, what steps are taken to deal with an unusual rush of passengers ?	Steam train.	Steam train.
7. *Are the journeys operated by rail motor cars (R.M.) subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection ?*	Yes.	Yes.
8. *Is your programme for use of R.M. cars on secondary lines limited to certain extra services interpolated between pre-existing services worked by steam locomotives ?*	Replace steam.	Replace steam.

*Light weight only.

Minneapolis, St. Paul and Sault St. Marie. 4' 8 1/2". 10	New York, New Haven and Hartford. 4' 8 1/2". 11	Northern Pacific. 4' 8 1/2". 12	Reading Company. 4' 8 1/2". 13
96° F.	100° F.	110° F.	101° F.
—41° F.	1° F.	—45° F.	13° F.
71° F.	69.6° F.	90° F.	72° F.
—6° F.	29.5° F.	—25° F.	32° F.
1	23	20	8
186	2.5	13 1/2	11.1
...	81.2	260	73.2
372	2 528	4 224	1 690
372	70	176	106
7.45	2.9	4.7	1.8
1 % (2 000 ft.).	2.5 % (500 ft.).	2.2 % (10.7 miles)	1.33 % (4 000 ft.).
...	9.66 (1.17 % av.).	15 (1.9 %)	3.75 (1.13 % av.).
955	420	382	358
28.6	25.8	26.7	24.8
85 400	30 290	77 920*	38 000
...	129 720	166 600	186 200
...	75 400	106 300	144 100
87 750	...	58 230	64 600
...	80 000	119 800	131 450
...	...	194 000	84 070
...	...	...	222 950
173 150	209 720	466 600 approx.	572 150
No.	No.	Yes.	No.
Steam train.	Steam train.	Trailer added or steam train used.	Steam train.
Yes.	Yes.	Yes.	Yes.
Replace steam. (Local service).	Replace steam.	Replace steam.	Replace steam.

1. *Name of railway.*	**Missouri-Pacific.**	**Missouri-Kansas-Texas.**
Gauge.	4' 8 1/2".	4' 8 1/2".
1	8	9
Have you used R.M. cars to cover complete passenger service on some branch or small line?	Yes.	Yes.
Treatment of freight traffic when mixed trains are replaced.	None replaced.	No change in freight service.
9. *Does your service programme comprise an extended use of R.M. cars on main lines?*	No.	No.
If so, what would be essentially your object?	...	...
Have stopping services on main lines, before or after express train, been tried?	No.	No.
10. *Have you considered using R.M. cars to establish, at moderate cost, temporary experimental communications, to find out passenger movement, with a view to transferring them, after certain experimental period and in case of good results, to loco.-hauled trains or doing away with them in contrary case? Have you any example?*	No.	No.
11. *Have you assigned, for preference, R.M. cars to certain local runs worked on Sundays and holidays?*	No.	No.
Are days out of service used for washing and maintenance of cars, so as to work service with smaller number of reserve R.M. cars?	...	...
12. *Are reserve cars available locally to provide relief for purpose of carrying out running repairs or the like?*	No.	No.
13. *Are reserve cars available generally to replace vehicles withdrawn for general overhaul?*	No.	No.
14. *For each type of R.M. car on your system, please state:*		
a) *Number at present existing;*	18	2
b) *Date of (I) oldest, (II) newest;*	(I) 1912, (II) 1926.	(I) 1925, (II) —
c) *Number effectively used daily;*	18	2
d) *Number out for repairs, etc.;*	0	0
e) *Annual average mileage per unit.*	69 350**	41 500
15. *For R.M. cars with single compartment for driver at one end, please say if at end of run R.M. car is always turned on a turntable.*	Yes.	Yes, on turntable or wye.

** Must include trailer mileage.

Minneapolis, St. Paul and Sault St. Marie. 4' 8 1/2". 10	New York, New Haven and Hartford. 4' 8 1/2". 11	Northern Pacific. 4' 8 1/2". 12	Reading Company. 4' 8 1/2". 13
No.	Yes.	Yes.	Yes.
None replaced.	None replaced.	Motors only replace steam where they can handle all traffic.	Only case occurs Pickering Val. Br.
No.	Not at present.	They are used to reduce costs.	Programme practically complete.
...	...	...	...
No.	...	Yes.	Not to date but may do so.
No.	On one run, results poor.	No.	No.
Yes.	Not necessarily.	No, but many services do not run Sundays.	No.
...	Yes.	Yes.	No.
No.	Yes. Mech. drive cars.	No.	Yes.
No.	Yes. Mech. drive cars.	No.	No.
1	36	24	16
(I) 1925, (II) —	(I) 1921, (II) 1927.	(I) 1924, (II) 1930.	...
1	25	22 1/2	12
0	11	1 1/2	4
75 900	19 700	62 900	30 200
Yes.	Yes, on turntable or wye.	Yes.	Yes.

1. *Name of railway.* *Gauge.* 1	**Missouri-Pacific.** 4' 8 1/2". 8	**Missouri-Kansas-Texas.** 4' 8 1/2". [illegible]
In contrary case, what is the maximum speed permissible for reverse running ?	...	...
On shuttle services, is propelling of trailers permitted, to avoid shunting ?	...	...
If so, what is maximum speed allowed ?	...	...
16. *Do your R.M. cars use locomotive sheds for stabling and maintenance, or have separate sheds been provided ?*	Loco. sheds.	Loco. sheds.
Are they looked after by locomotive staff or have you a specialist staff ?	Loco. staff.	Special staff.
Are cars stabled under cover, or in the open ?	Some under cover. Some in open.	Under cover.
17. *Is operating staff provided and controlled wholly by mechanical department, transportation department, or partly by each department ?*	Jointly.	Transportation.
18. *State the number of men used for driving. What branch ? State number of men used in addition to the above mentioned driving staff, giving the department of service to which they belong :*	One man. Mechanical.	One man.
a) For R.M. car running alone;	Conductor.	Conductor, baggageman.
b) *For motor car hauling one or more trailers.*	Conductor.	...
Any special points governing the number ?	Transportation.	...
19. *In the event of failure en route, what special provision, if any, is made for clearing the section ?*	Same as for steam.	Same as for steam.
20. *Is special staff employed on the supervision or superintendence of R.M. operation ? Please give an outline of the organisation and duties of such staff.*	Motor car supervisor. Travelling assistant.	No.
21. *To facilitate maintenance, do you provide spare engines and other parts ? If so, to what extent ? How are such spare parts controlled and used ?*	Yes, one spare truck and engine for mech. drive. Stock of service parts for elec. drive.	No engines. Few stock small parts.

Minneapolis, St. Paul and Sault St. Marie. 4' 8 1/2". 10	**New York, New Haven and Hartford.** 4' 8 1/2". 11	**Northern Pacific.** 4' 8 1/2". 12	**Reading Company.** 4' 8 1/2". 13
...	...	...	...
...	Only in shunting.	...	Yes.
..	Speed inconsiderable.	...	...
Loco. sheds.	Both.	Loco. sheds.	Separate sheds in two places. In open elsewhere.
Loco. staff.	Special staff.	Specially trained loco. staff.	Loco. staff.
Under cover.	Under cover where possible.	Both.	Both.
Mechanical.	...	Jointly.	Transportation.
One man.	One man. Transportation.	One man. Mechanical.	One man.
...	Conductor.	Conductor.	1 conductor. 1 flagman.
Conductor, brakeman and baggageman.	Varies in different States.	Conductor and when more than one trailer, brakeman.	ditto.
...	Transportation. Apparently local regulations.	Transportation. Sometimes baggageman and mail clerk. Depends on type of car.	...
Same as for steam.	Same as for steam.	Same as for steam.	Same as for steam.
No.	Engr. of auto equipt. 2 mech. inspectors.	Motor car supervisor.	No.
No.	Yes.	No engines. Spare elec. motors and parts carried at local stores.	No, only small spare parts carried.

1. *Name of railway.* *Gauge.* 1	**Southern Pacific.** 4' 8 1/2". 14	**Canadian National.** 4' 8 1/2". 15
2. *Temperature conditions of country:*		
a) *Max. Summer temperature*	...	99° F.
b) *Min. Winter temperature.*	...	—42° F.
c) *Mean Summer temperature for one day.*	...	Mean daily range = 18° F.
d) *Mean Winter temperature for one day.*	...	
3. a) *Number of services.*	18	43
b) *Shortest run* — miles.	53	17
c) *Longest run* — miles	144	355
d) *Total daily mileage — all cars*	5 617	8 204
e) *Average daily mileage per car.*	244	152
4. a) *Average distance between stops,* miles.	...	4.35
b) *Steepest grade %*	...	2.0 % (3 miles)
c) *Longest grade* — miles	...	...
d) *Sharpest curve* — feet radius	...	249 ft.
e) *Average speed* — m. p. h.	...	25.6
5. *Weight of rail motor (R.M.)* — lb. Min.	118 000**	8 000
Max.	167 500	206 000
Aver.	146 130	100 300
Weight of trailer — lb. Min.	...	40 000
Max.	...	96 000
Aver.	...	69 000
Average weight of train — lb.	...	147 600
Maximum weight of train — lb.	...	296 000
6. *From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table, and effected by means of rail motor cars?*	...	Yes.
Are they considered as trains having limited seating accommodation?		
In the contrary case, what steps are taken to deal with an unusual rush of passengers?	...	Steam train.
7. *Are the journeys operated by rail motor cars (R.M.) subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection?*	...	Yes, except exclusively local services.
8. *Is your programme for use of R.M. cars on secondary lines limited to certain extra services interpolated between pre-existing services worked by steam locomotives?*	...	Replace steam.

Light weight only. — * Weight of steam cars only given.

Japanese Government. 3’ 6”. 16	Chosen Government. 4’ 8 1/2” and 3’ 6”. 17	Federated Malay States. 3’ 3 3/8” (metre). 18	East Indian. 5’ 6”. 19
98° F.	91° F.	98° F.	120° F.
16.5° F.	13.8° F.	67° F.	30° F.
78° F.	78.5° F.	...	110° F.
37° F.	29.5° F.	...	40° F.
14	7	1	3
1.7	1.6	12	19
10.6	114	32	59
1 110	1 472	80	314
40	70	80	105
...	...	2	3.9
2 %	2.5 % (5 800 ft.).	1 % (1 mile).	0.5 % (1.4 mile).
...	1.13 (2.5 %).	1.9 (0.5 % av.).	9.5 (0.3 % av.).
659 ft.	3 840 ft.	782 ft.	1 432 ft.
...	25	16.7	21.3
...	13 000	105 700	104 000
68 800***	119 500	...	...
...	48 800	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	48 800	105 700	104 000
68 800	119 500	105 700	104 000
...	Yes.	No.	Yes.
...	No relief.	...	Steam train.
...	Some.	In some cases.	Yes, in some cases.
...	Interpolated.	Replace steam	Interpolated.

1. *Name of railway.*	**Southern Pacific.**	**Canadian National.**
Gauge	4' 8 1/2''.	4' 8 1/2''.
1	14	15
Have you used R.M. cars to cover complete passenger service on some branch or small line ?	...	Yes.
Treatment of freight traffic when mixed trains are replaced.	...	Freight service handled by steam.
9. *Does your service programme comprise an extended use of R.M. cars on main lines ?*	...	Yes.
If so, what would be essentially your object?	...	To improve service at moderate cost.
Have stopping services on main lines, before or after express train, been tried ?	...	...
10. *Have you considered using R.M. cars to establish, at moderate cost, temporary experimental communications, to find out passenger movement, with a view to transferring them, after certain experimental period and in case of good results, to loco.-hauled trains or doing away with them in contrary case ? Have you any example ?*	...	No.
11. *Have you assigned, for preference, R.M. cars to certain local runs worked on Sundays and holidays ?*	...	Yes.
Are days out of service used for washing and maintenance of cars, so as to work service with smaller number of reserve R.M. cars?	...	Daily maintenance.
12. *Are reserve cars available locally to provide relief for purpose of carrying out running repairs or the like ?*	...	Only in three cases.
13. *Are reserve cars available generally to replace vehicles withdrawn for general overhaul ?*	...	No.
14. *For each type of R.M. car on your system, please state :*		
a) *Number at present existing;*	...	54
b) *Date of (I) oldest, (II) newest;*	...	(I) 1923, (II) 1931.
c) *Number effectively used daily;*	...	46
d) *Number out for repairs, etc.;*	...	9
e) *Annual average mileage per unit.*	67 400	36 000
15. *For R.M. cars with single compartment for driver at one end, please say if at end of run R.M. car is always turned on a turntable.*	...	Yes, on turntable or wye.

Japanese Government. 3' 6". 16	Chosen Government. 4' 8 1/2" and 3' 6". 17	Federated Malay States. 3' 3 3/8" (metre). 18	East Indian. 5' 6". 19
...	No.	No.	Yes, for a short period.
...	Not affected.	...	Freight trains run.
...	Yes.	No.	Yes.
...	To improve service.	...	To improve facilities, and compete with road.
...	No.	Under consideration.	Not warranted.
...	Yes.	No.	Yes, in several cases with good results.
...	No difference made for Sundays.	No.	Yes.
...	...	...	Yes.
...	Yes.	Not at present.	No.
...	Yes.	Not at present.	No.
28	21	1	3
(I) 1912, (II) 1929	(I) 1923, (II) 1930.	(I) 1930, (II) —	(I) 1928, (II) —
14	14	1	3
6.4 (?)	7	0	0
12 000 (based on 300 days p. a.).	25 000	28 000	27 000
Double-end control.	Yes, on turntable.	Double-end control.	Double-end control.

1. *Name of railway.* *Gauge.* 1	**Southern Pacific.** 4' 8 1/2". 14	**Canadian National.** 4' 8 1/2". 15
In contrary case, what is the maximum speed permissible for reverse running ?	...	...
On shuttle services, is propelling of trailers permitted, to avoid shunting ?	...	No.
If so, what is maximum speed allowed ?	...	...
16. *Do your R.M. cars use locomotive sheds for stabling and maintenance, or have separate sheds been provided ?*	...	Loco. sheds.
Are they looked after by locomotive staff or have you a specialist staff ?	...	Special staff. One maintainer for each car.
Are cars stabled under cover, or in the open ?	...	In outlying places in open.
17. *Is operating staff provided and controlled wholly by mechanical department, transportation department, or partly by each department ?*	...	Transportation
18. *State the number of men used for driving. What branch ? State number of men used in addition to the above mentioned driving staff, giving the department of service to which they belong :*	...	One man (loco. engr.).
a) For R.M. car running alone;	...	Conductor only usually.
b) *For motor car hauling one or more trailers.*	...	Two or three.
Any special points governing the number ?	...	Depends on local conditions.
19. *In the event of failure en route, what special provision, if any, is made for clearing the section ?*	...	Same as for steam.
20. *Is special staff employed on the supervision or superintendence of R.M. operation ? Please give an outline of the organisation and duties of such staff.*	...	Unit rail car supervisors (report to supt. motive power).
21. *To facilitate maintenance, do you provide spare engines and other parts ? If so, to what extent ? How are such spare parts controlled and used ?*	...	No engines. Other spare parts at main stores 10 %.

Japanese Government. 3' 6". 16	Chosen Government. 4' 8 1/2" and 3' 6". 17	Federated Malay States. 3' 3 3/8" (metre). 18	East Indian. 3' 6". 19
...	9-15 m. p. h.	...	...
...	In shunting only.	Trailers not used.	...
...	...	...	...
No separate sheds.	Loco. sheds.	Loco. sheds.	Loco. sheds.
Local staff.	Same staff.	Loco staff.	Loco staff.
In open.	In open now, cover being provided.	Under cover.	Under cover.
By electrical department.	Transportation.	Transportation.	Transportation.
Two for steam. One for petrol.	One driver.	One driver. One fireman.	One driver. One fireman.
...	Steam:	One.	One.
...	Fireman and conductor. Petrol: conductor. No trailers.	...	...
...	...	...	...
Same as for steam.	Same as for steam.	Same as for steam.	Same as for steam
No.	No.	No	No.
No.	Yes.	No engines or boilers. Stock of small spares.	No.

1. *Name of railway.* *Gauge*	Nigerian. 3' 6".	Sudan Government. 3' 6".
1	20	21
2. *Temperature conditions of country :*		
a) *Max. Summer temperature*	110° F.	114° F.
b) *Min. Winter temperature.*	58° F.	47° F.
c) *Mean Summer temperature for one day.*	...	87° F.
d) *Mean Winter temperature for one day.*	...	76° F.
3. a) *Number of services.*	2	1
b) *Shortest run* — miles.	2	34
c) *Longest run* — miles	38	...
d) *Total daily mileage — all cars*	175.5	137
e) *Average daily mileage per car.*	88	69
4. a) *Average distance between stops,* miles.	4.0	5.7
b) *Steepest grade %*	1 % (3.5 miles).	0.33 % (6 300 ft.).
c) *Longest grade* — miles	6.2 (0.77 % av.).	...
d) *Sharpest curve* — feet radius	660 ft.	3 820 ft.
e) *Average speed* — m. p. h.	17.3	20.2
5. *Weight of rail motor (R.M.)* — lb. Min.	...	58 800*
Max.	...	...
Aver.	...	...
Weight of trailer — lb. Min.	...	...
Max.	...	...
Aver.	...	...
Average weight of train — lb.	...	...
Maximum weight of train — lb.	...	58 800
6. *From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table, and effected by means of rail motor cars ?*	No.	Yes.
Are they considered as trains having limited seating accommodation ?		
In the contrary case, what steps are taken to deal with an unusual rush of passengers ?	Question not arisen.	No relief.
7. *Are the journeys operated by rail motor cars (R.M.) subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection ?*	Yes.	No. Purely local.
8. *Is your programme for use of R.M. cars on secondary lines limited to certain extra services interpolated between pre-existing services worked by steam locomotives ?*	No.	Interpolated.

*Light weight only.— **Weight of petrol cars only given.

South African. 3' 6'' and 2' 0''. 22	New Zealand Government. 3' 6''. 23	Western Australian Government. 3' 6''. 24	Tasmanian Government. 3' 6''. 25
102° F.	75.1° F.	85° F.	...
27° F.	38.5° F.	42° F.	...
84° F.	65.4° F.	74° F.	...
49° F.	42.5° F.	55° F.	...
6	2	2	5
43	17	35	14
182	36	71	54
862	286	164	415
51	143	55	46
5.0	2.9	2.5	1.9
2.5 % (1.8)	1.41 % (950 ft.).	1.67 % (2 960 ft.).	2.5 % (3 miles).
4.2 (2.1 % av.). 21.6 (1.22 % av.).	...	4.4 (1.18 % av.).	6.4 (1.95 % av.)
396 ft.	482 ft.	660 ft.	330 ft.
20.6	26.7	15.1	18
...	54 800	27 400	20 160
36 850**	73 920	82 800	42 300
...	64 350	45 900	31 300
...	...	10 000	...
...	...	38 600	24 300
...	...	24 300	...
...	64 350	79 400	34 000
36 850	73 920	121 400	66 600
Yes.	Yes.	Yes at Albany. No at Perth.	...
Another R. M. or steam train.	Steam train.	Steam train.	...
Yes, also independent services.	Independent local services.	Yes at Albany. No at Perth.	..
Replace steam.	Replace steam.	Interpolated.	...

1. *Name of railway* . . . . *Gauge*	**Nigerian.** 3' 6''. 20	**Sudan Government.** 3' 6''. 21
Have you used R.M. cars to cover complete passenger service on some branch or small line ?	No.	No.
Treatment of freight traffic when mixed trains are replaced.	Does not arise.	Not affected.
9. *Does your service programme comprise an extended use of R.M. cars on main lines ?*	Yes.	Cars still experimental.
If so, what would be essentially your object?	To improve facilities and compete with road.	...
Have stopping services on main lines, before or after express train, been tried ?	...	Under consideration.
10. *Have you considered using R.M. cars to establish, at moderate cost, temporary experimental communications, to find out passenger movement, with a view to transferring them, after certain experimental period and in case of good results, to loco.-hauled trains or doing away with them in contrary case ? Have you any example ?*	No.	Yes. Berber — Atbara.
11. *Have you assigned, for preference, R.M. cars to certain local runs worked on Sundays and holidays ?*	No.	No.
Are days out of service used for washing and maintenance of cars, so as to work service with smaller number of reserve R.M. cars?	...	...
12. *Are reserve cars available locally to provide relief for purpose of carrying out running repairs or the like ?*	No.	No.
13. *Are reserve cars available generally to replace vehicles withdrawn for general overhaul ?*	No.	No.
14. *For each type of R.M. car on your system, please state :*		
a) *Number at present existing;*	2	2
b) *Date of (I) oldest, (II) newest;*	(I) 1929, (II) 1930.	(I) 1929, (II) —
c) *Number effectively used daily;*	2	1
d) *Number out for repairs, etc.;*	0	1
e) *Annual average mileage per unit.*	28 000	22 250
15. *For R.M. cars with single compartment for driver at one end, please say if at end of run R.M. car is always turned on a turntable.*	Double-end control.	Double-end control.

South African. 3' 6" and 2' 0". 22	New Zealand Government. 3' 6". 23	Western Australian Government. 3' 6". 24	Tasmanian Government. 3' 6". 25
Yes.	Yes.	No.	...
Some cases freight trains on alt. days.	Existing freight service sufficient.	Existing freight service sufficient.	...
Not at present, but under consideration.	No.	No.	...
Combat road competition.	...	...	...
...	...	No.	...
This stage not yet reached.	No.	No.	...
No.	No.	No.	...
Yes.	...	...	...
In some cases.	No.	Yes at Albany. No at Perth.	...
Not at present, but contemplated.	No.	Yes at Albany. No at Perth.	...
19	2	3	...
(I) 1922, (II) 1931.	(I) 1925, (II) —	(I) 1922, (II) 1930.	...
15	2	2	...
4	0	1	...
30 000	20 500 for steam. 50 400 for battery.	14 000	13 300
Yes, on turntable or wye.	Double-end control.	Double-end control.	...

1. *Name of railway.*	**Nigerian.**	**Sudan Government.**
Gauge 1	3' 6". 20	3' 6". 21
In contrary case, what is the maximum speed permissible for reverse running ?	...	...
On shuttle services, is propelling of trailers permitted, to avoid shunting ?	Trailers not used but propelling would not be permitted except in shunting.	...
If so, what is maximum speed allowed ?	...	...
16. *Do your R.M. cars use locomotive sheds for stabling and maintenance, or have separate sheds been provided ?*	Loco. sheds.	Loco. sheds.
Are they looked after by locomotive staff or have you a specialist staff ?	Loco. staff.	Same staff.
Are cars stabled under cover, or in the open ?	Under cover.	Under cover.
17. *Is operating staff provided and controlled wholly by mechanical department, transportation department, or partly by each department ?*	Transportation.	Jointly.
18. *State the number of men used for driving. What branch ? State number of men used in addition to the above mentioned driving staff, giving the department of service to which they belong :*	One driver. One fireman.	One driver. Mechanical.
a) For R.M. car running alone;	One.	1 fireman (mech.) 1 guard (trans.).
b) *For motor car hauling one or more trailers.*	...	No trailers.
Any special points governing the number ?	...	...
19. *In the event of failure en route, what special provision, if any, is made for clearing the section ?*	Same as for steam.	Same as for steam.
20. *Is special staff employed on the supervision or superintendence of R.M. operation ? Please give an outline of the organisation and duties of such staff.*	No.	No.
21. *To facilitate maintenance, do you provide spare engines and other parts ? If so, to what extent ? How are such spare parts controlled and used ?*	No engine. Stock of small spares.	Limited stock of spares.

South African. 3' 6" and 2' 0". [illegible]	New Zealand Government. 3' 6". 23	Western Australian Government. 3' 6". 24	Tasmanian Government. 3' 6". 25
...	...	...	...
...	...	...	...
...	...	..	...
Loco. sheds not used.	Loco. shed—steam car. Separate—battery.	Loco. sheds.	...
Car drivers do maintenance.	Loco. staff.	Loco. staff.	...
In open.	Under cover.	Under cover.	...
Transportation.	Jointly.	Transportation.	...
One for petrol cars.	Driver and fireman for steam car. Driver only for battery car.	Driver and fireman-steam. Driver only-petrol.	...
One.	...	None.	...
...	...	None.	...
...	...	...	...
Same as for steam. Portable telephones.	Same as for steam.	Same as for steam.	...
No.	No.	No.	...
Spare parts held by main stores.	Limited stock of small spares.	One spare engine for petrol cars.	...

1. *Name of railway.* *Gauge*	**New South Wales Government.** 4' 8 1/2''. [illegible]	**New York Central.** 4' 8 1/2''. 27
2. *Temperature conditions of country :*		
a) *Max. Summer temperature*	108.5° F.	102° F.
b) *Min. Winter temperature.*	36° F.	13° F.
c) *Mean Summer temperature for one day.*	70° F.	80° F.
d) *Mean Winter temperature for one day.*	56° F.	26° F.
3. a) *Number of services.*	36	25
b) *Shortest run* — miles.	5	7.25
c) *Longest run* — miles	178	245
d) *Total daily mileage — all cars*	3 945	4 597
e) *Average daily mileage per car.*	107	139
4. a) *Average distance between stops*, miles.	5	3.3
b) *Steepest grade %*	4 % (990 ft.).	3.34 % (530 ft.).
c) *Longest grade* — miles	8.4 (2.2 %).	3 (2.54 % av.). 12 1/2 (1.25 % av.).
d) *Sharpest curve* — feet radius	528 ft.	435 ft.
e) *Average speed* — m. p. h.	24.25	28.8
5. *Weight of rail motor (R.M.)* — lb. Min.	38 700	70 000
Max.	46 200	185 000
Aver.	42 900	128 000
Weight of trailer — lb. Min.	19 400	41 550*
Max.	44 200	134 400*
Aver.	33 750	92 650*
Average weight of train — lb.	55 070	220 650
Maximum weight of train — lb.	90 400	407 600
6. *From the point of view of passenger transport conditions, do you notify the public which are the runs provided for in the time-table, and effected by means of rail motor cars ?*	Yes.	Yes.
Are they considered as trains having limited seating accommodation ?		
In the contrary case, what steps are taken to deal with an unusual rush of passengers ?	Trailer added or steam train used.	Steam train.
7. *Are the journeys operated by rail motor cars (R.M.) subject to predetermined connections with other trains, or are they exclusively local in character, independent of any connection ?*	Yes.	Yes.
8. *Is your programme for use of R.M. cars on secondary lines limited to certain extra services interpolated between pre-existing services worked by steam locomotives ?*	Replace steam.	Replace steam.

* Light weight only.

1. *Name of railway.* . . . . *Gauge.* 1	**New South Wales Government.** 4' 8 1/2''. 26	**New York Central.** 4' 8 1/2''. 27
Have you used R.M. cars to cover complete passenger service on some branch or small line ?	Yes. Sometines mixed train used on alt. days.	Yes.
Treatment of freight traffic when mixed trains are replaced.	Otherwise existing freight service sufficient.	Not affected. Steam locos. used for livestock.
9. *Does your service programme comprise an extended use of R.M. cars on main lines ?*	Not at present.	No.
If so, what would be essentially your object?	...	...
Have stopping services on main lines, before or after express train, been tried ?	No.	No.
10. *Have you considered using R.M. cars to establish, at moderate cost, temporary experimental communications, to find out passenger movement, with a view to transferring them, after certain experimental period and in case of good results, to loco.-hauled trains or doing away with them in contrary case ? Have you any example ?*	Yes. Bankstown-Lidcombe.	Yes. Lafayette to Indianapolis. Not successful.
11. *Have you assigned, for preference, R.M. cars to certain local runs worked on Sundays and holidays ?*	No, but many do not run Sundays.	No.
Are days out of service used for washing and maintenance of cars, so as to work service with smaller number of reserve R.M. cars?	Yes.	Yes.
12. *Are reserve cars available locally to provide relief for purpose of carrying out running repairs or the like ?*	Yes.	No.
13. *Are reserve cars available generally to replace vehicles withdrawn for general overhaul ?*	Yes.	No.
14. *For each type of R.M. car on your system, please state :*		
a) *Number at present existing;*	37	33
b) *Date of (I) oldest, (II) newest;*	(I) 1923, (II) 1930.	(I) 1925, (II) 1930.
c) *Number effectively used daily;*	30	30
d) *Number out for repairs, etc.;*	7	3
e) *Annual average mileage per unit.*	31 000	36 500
15. *For R.M. cars with single compartment for driver at one end, please say if at end of run R.M. car is always turned on a turntable.*	Double-end control.	Single-end cars always turned.

1. *Name of railway.* *Gauge.*	**New South Wales Government.** 4' 8 1/2".	**New York Central.** 4' 8 1/2". 27
In contrary case, what is the maximum speed permissible for reverse running ?	...	Not done in service.
On shuttle services, is propelling of trailers permitted, to avoid shunting ?	Only in shunting.	No shuttle services.
If so, what is maximum speed allowed ?	10 m. p. h.	...
16. *Do your R.M. cars use locomotive sheds for stabling and maintenance, or have separate sheds been provided ?*	Loco. sheds not used.	Loco. sheds.
Are they looked after by locomotive staff or have you a specialist staff ?	Special staff.	Same staff.
Are cars stabled under cover, or in the open ?	Both.	Both.
17. *Is operating staff provided and controlled wholly by mechanical department, transportation department, or partly by each department ?*	Jointly.	Transportation.
18. *State the number of men used for driving. What branch ? State number of men used in addition to the above mentioned driving staff, giving the department of service to which they belong :*	One driver. Mechanical.	One man.
a) *For R.M. car running alone;*	One.	Two men.
b) *For motor car hauling one or more trailers.*	One.	Two trailers, 2 men. Three or more trailers, 3 men.
Any special points governing the number ?	Transportation.	Depends on number of cars.
19. *In the event of failure en route, what special provision, if any, is made for clearing the section ?*	Same as for steam. Tricycle and portable telephone carried.	Same as for steam.
20. *Is special staff employed on the supervision or superintendence of R.M. operation ? Please give an outline of the organisation and duties of such staff.*	Rail motor supervisor. Travelling mechanic. Asst. engr. on design and workshop.	Equipment engineering dept. and staff of inspectors.
21. *To facilitate maintenance, do you provide spare engines and other parts ? If so, to what extent ? How are such spare parts controlled and used ?*	Yes. 10 % approx.	Yes. Definite list for each type of car.

PART II.

PARTICULARS OF CARS.

Name of railway	**Baltimore and Ohio.**	**Boston and Maine.**
Brief particulars of cars other than those listed below. *Type, horse-power and number*	Gas-mechanical: 65 H. P.—1 car. 190 H. P.—1 car. Gas-electric: 250 H. P.—16 cars.	Gas-mechanical: 68 H. P.—1 car. 190 H. P.—6 cars. Gas-electric: 175 H. P.—1 car. 200 H. P.—3 cars. 250 H. P.—3 cars. 275 H. P.—8 cars.
Type of car 1	600 H. P. petrol-elect. 2	275 H. P. petrol-elect. 3
1. *Number of 2-axle cars*	...	...
» *3-axle cars*	...	...
» *2-bogie (truck) cars*	1	2
» *articulated cars*	...	...
2. *Diagrams of rail motor cars (elevation and plan), preferably to scale of 1 : 100 for each class of car mentioned in (1) above. Following information should be given :*	All-steel.	...
Number of motor axles	4	2
Number of coupled axles	Nil.	Nil.
Gauge of track	4' 8 1/2"	4' 8 1/2"
Total wheel-base	60' 9"	62'
Distance between centres of bogie (truck) axles.	7' 0" both. bogies.	7' 0" driving. 6' 0" trailing.
Diameter of wheels	36"	33"
Length over buffers	75' 5"	76'
Length of body	73'	73'
Internal width and height of compartments.	9' 6" × 8' 0" approx.	9' 8" × 8' 4"
Type of journal bearings	S. K. F. roller.	A. R. A.
3. *Weight of rail motor car unloaded*	...	105 000 lb.
In service, fuelled complete (fuel, water, etc.), but without passengers, baggage or mails.	161 875 lb. Front axles — 50 123 lb. Rear » — 30 812 lb.	...
In service fuelled complete, and with maximum load of passengers, baggage and mails	179 025 lb.	...
In each of the above cases give distribution of weight on each axle.	...	...
Weight (light) of engine alone when it constitutes a separate chassis.	Nil.	...
4. *What classes are provided ?*	One class.	One class.
Seating accommodation for each class (give diagram).	46 seats	84 seats.
Size and maximum load capacity of baggage compartment.	17' 1" × 9' 8"	12' × 9' 8"
Size and maximum load capacity of mail compartment.	...	Nil.

articulars of cars.

Central of Georgia.	Chesapeake and Ohio.	Great Northern.	Gulf Coast and International Gt. Northern.
Nil.	Gas-mechanical : 90 H. P.—4 cars.	Gas-electric : 175 H. P.—9 cars. 220 H. P.—2 cars. 250 H. P.—2 cars. 275 H. P.—13 cars. 300 H. P.—1 car. 400 H. P.—7 cars.	Nil.
90 H. P. petrol-mech. 4	275 H. P. petrol-elect. 5	400 H. P. oil-elect. 6	220 H. P. petrol-elect. 7
...	...	...	...
...	...	...	...
1	6	1	8
...	...	...	...
...	All steel.	All steel.	...
2	2	2	2
Nil.	Nil.	Nil.	Nil.
4' 8 1/2"	4' 8 1/2"	4' 8 1/2"	4' 8 1/2"
28' 10"	64' 11 5/8"	60' 0"	...
6' 8" both bogies.	7' 4" driving 6' 4" trailing	7' 10" driving. 6' 6" trailing.	... ...
30"	33"	36"	33"
43' 1"	...	74'	70' 7 3/8"
41' 10"	76' 7 5/8"	72'	...
9' 1" × 7' 6"	9' 3" × 8' 0" approx.	9' 5" × 8' 0"	9' 6" wide.
Timken roller.	Hyatt roller.	S. K. F. roller.	...
32 000 lb.	130 000 lb.	...	...
...	...	147 780 lb.	Drvg. bogie — 60 % Trail. » — 40 %
...	...	165 280 lb.	...
...	...	...	...
Nil.	...	Nil.	Nil.
One class. 29 seats.	One class. 40 seats.	One class. No passengers.	One class. 48 to 64 seats.
17' 8" × 9' 1" baggage and mails.	19' 10" × 9' 3"	9' 0" × 9' 5" fish. 32' × 9' 5" baggage.	20' 9" × 9' 6".
...	15' 1" × 9' 3"	15'2" × 9' 5" mail. Total cap. 17 500 lb.	...

Name of railway	**Baltimore and Ohio.**	**Boston and Maine.**
Type of drive 1	600 H. P. petrol-elect. 2	275 H. P. petrol-elect. 3
5. *Size and position of engine compartment.* .	16' 5" × 9' 8" End of car.	9' 7 3/8" × 9' 8" End of car over driving bogie.
Size and position of driver's compartment or compartment.	In engine compartment only.	In engine compt. and small cabin at opposite end.
6. *For trailer purposes, are standard vehicles used, or has specially constructed stock been adopted ?*	Converted steam cars and special stock. Many types.	Both. Special light weight cars used for smaller cars.
Give particulars of weights, accommodation, and seating arrangements.	All-steel special pass. and baggage trailer. Light wgt. 144 800 lb.- 48 seats 20 000 lb. of baggage.	Weight not given. 49 to 93 seats. One type has 15' mail compartment.
Is any provision made for smoking, either in motor cars on trailers.	Smoking provided for in motor car, 46 seats.	Compartment for 20 smokers in motor car.
7. *Are rail motors fitted with standard buffers and couplings ?*	Yes.	No. Light weight standard contour couplers and buffers.
Will the same answer apply to specially constructed trailers ?	Yes.	Yes.
8. *Braking methods.*	Westinghouse.	Westinghouse A. M. M.
Continuous braking (specify the system):		
Screw brake	Lindstrom lever and Peacock staffless.	...
Lever Brake	...	...
Steam brake	...	...
For each braking apparatus please state if it acts on all the wheels of the car or on part only.	All wheels.	All wheels.
What percentage of brake power is provided in the main braking apparatus ?	80 % of light weight.	95 % on driving bogie, 90 % on trailing bogie.
9. *Heating system of rail motors and trailers and how controlled.*	Hot water, manual control.	Hot water heating.
Lighting system for car, head, and tail lights.	Electric (32-volt). from storage battery.	Electric light.
10. *If the weight of R.M. is limited in any way by condition of track or bridges, please give :*		
Maximum permissible axle load.	No limitation.	No limitation.
Weight of rails per yard.	130-lb. rails,	
Length of rails.	39' long, 22 ties	
Number of supports (sleepers-ties) for each rail length.	per rail.	
11. *Approx. light weight of standard type vehicle, which most closely resembles the R.M. in respect to comfort, good riding and carrying capacity.*	...	Old style combination car, 90 000 lb.

Central of Georgia.	**Chesapeake and Ohio.**	**Great Northern.**	**Gulf Coast and International Gt. Northern.**
90 H. P. petrol-mech. [illegible]	275 H. P. petrol-elect. [illegible]	400 H. P. oil-elect. 6	220 H. P. petrol-elect. 7
In baggage compartment over driving bogie.	11' 10"×9' 3". End of car over driving bogie.	15' 6"×9' 5". End of car over driving bogie.	11' 11"×9' 6". End of car over driving bogie.
In baggage compartment only.	In engine compartment only.	In engine compartment only.	In engine compartment only.
No trailers.	Standard.	Standard vehicles of various types.	No trailers.
...	...	...	...
No.	Yes, in motor car, 13 seats.	One pass. type, lgt. wgt. 111 250 lb.	Yes.
No.	Yes.	Special for motor cars. Match with standard type.	Yes.
...	Yes.	...	...
Westinghouse semi-automatic air.	Westinghouse A. M. L.	Westinghouse A. M. L.	Westinghouse air.
...	...	...	...
Hand brake.	Standard hand brake.	...	Hand brake.
...	...	...	...
All wheels.	All wheels.	All wheels.	All wheels.
Unknown.	90 %	100 % at 50 lb. per sq. in. cylinder pressure.	...
Hot water, coal fired.	Hot water, manual control.	Hot water.	Hot water, manual control.
Electric (12-volt), from storage battery.	Electric.	Electric throughout.	Electric (32-volt), from storage battery.
No limitation.	No limitation.	No limitation.	No limitation.
Nothing similar.	155 000 lb.	Vehicle of like weight.	...

Name of railway	**Missouri-Pacific.**	**Missouri-Kansas and Texas.**
Brief particulars of cars other than those listed below. *Type, horse-power and number*	Gas-mechanical: 68 H. P.—7 cars. Gas-electric: 220 H. P.—10 cars.	Gas-mechanical: 175 H. P.—1 car.
Type of car 1	220 H. P. petrol-electr. 8	200 H. P. petrol-elect. 9
1. *Number of 2-axle cars.*	...	...
» *3-axle cars.*	...	...
» *2-bogie (truck) cars*	1	1
» *articulated cars*	...	...
2. *Diagrams of rail motor cars (elevation and plan), preferably to scale or 1 : 100 for each class of car mentioned in (1) above. Following information should be given :*	...	...
Number of motor axles.	2	2
Number of coupled axles	Nil.	Nil.
Gauge of track	4' 8 1/2''	4' 8 1/2''
Total wheel-base	60' 6''	60' 6''
Distance between centres of bogie (truck) axles.	6' 6'' both bogies.	6' 6'' both bogies.
Diameter of wheels	33''	33''
Length over buffers.	72' 9''	70' 9'' (?)
Length of body	70' 6''	70' 6''
Internal width and height of compartments.	9' 6''×8' 1''	9' 6''×8' 0 1/2''
Type of journal bearings	A. R. A.	A. R. A.
3. *Weight of rail motor car unloaded*	...	...
In service, fuelled complete (fuel, water, etc.), but without passengers, baggage or mails.	100 500 lb. Dvg. Axles — 29 625 lb. Trg. » — 20 625 lb.	77 720 lb.
In service, fuelled complete, and with maximum load of passengers, baggage and mails	119 500 lb.	97 720 lb. Dvg. 28 500 lb. Tlg. 20 360 lb.
In each of the above cases give distribution of weight on each axle.	...	...
Weight (light) of engine alone when it constitutes a separate chassis.	Nil.	Nil.
4. *What classes are provided ?*	One class.	One class.
Seating accommodation for each class (give diagram).	40 seats.	37 seats.
Size and maximum load capacity of baggage compartment	26' 0''×9' 6'' 13 000 lb.	19' 0''×9' 6'' 5 700 lb.
Size and maximum load capacity of mail compartment	...	...

Minneapolis, St. Paul and Sault Ste. Marie.	New York, New Haven and Hartford.	Northern Pacific.	Reading.
Nil.	Gas-mechanical: 40 H. P.—3 cars. 120 H. P.—18 cars. 180 H. P.—1 car. Gas-electric: 200 H. P.—1 car. Gas-hydraulic: 180 H. P.—1 car.	Petrol-electric: 175 H. P.—7 cars. 220 H. P.—4 cars. 275 H. P.—4 cars. 300 H. P.—7 cars.	Gas-mechanical: 68 H. P.—1 car. Gas-electric: 250 H. P.—4 cars. 330 H. P.—1 car. 360 H. P.—3 cars. 500 H. P.—3 cars. Oil-electric: 330 H. P.—2 cars.
175 H. P. petrol-elect. 10	250 H. P. petrol-elect. 11	600 H. P. petrol-elect. 12	600 H. P. petrol-elect. 13
...	...	...	...
...	...	...	...
1	12	2	2
...	...	...	...
...	...	...	...
2	2	4	4
Nil.	Nil.	Nil.	Nil.
4' 8 1/2"	4' 8 1/2"	4' 8 1/2"	4' 8 1/2"
47' 3"	61' 9"	62' 8"	61' 4 1/2"
6' 6" both bogies.	7' 6" driving. 7' 0" trailing.	7' 4" both bogies.	7' 10 1/2" both bogies.
33"	...	33"	36"
60' 2"	75' 10"	77' 0"	75'
58' 1 1/2"	73'	75' 0"	73'
...	9' 5" × 7' 6"	9' 2 1/2" × 8' approx.	9' 3" × 8' 11 1/2"
A. R. A.	A. R. A.	Roller.	A. R. A.
75 700 lb.	...	166 400 lb. Eng. end — 51 600 lb. Other » — 31 595 lb.	...
79 900 lb.	101 495 lb. Dvg. axles — 31 078 lb. Tlg. » — 19 670 lb.	...	163 250 lb. Front axles — 47 195 lb. Rear » — 34 430 lb.
97 700 lb.	120 535 lb. Dvg. — 35 348 lb. Tlg. — 24 920 lb. (A few of the cars vary slightly from above weights).	197 000 lb. approx.	181 000 lb. (Above are average weights).
...	...	...	...
Nil.	...	Nil.	Nil.
One class. 52 seats.	One class. 70 seats.	One class. No passengers in these cars.	One class only. 24 seats.
...	11' 3" × 9' 5" 4 000 lb.	41' 6" × 9' 2 1/2" approx. 20 500 lb. approx.	20' 4 1/2" × 9' 3" 9 750 lb. (avge).
...	Nil.	15' × 9' 2 1/2" 5 000 lb.	15' 2" × 9' 3" 5 000 lb.

Name of railway	**Missouri-Pacific.**	**Missouri-Kansas and Texas.**
Type of car	220 H. P. petrol-electr. 8	200 H. P. petrol-elect. 9
5. *Size and position of engine compartment.*	8' 6" × 9' 6". End of car over driving bogie.	7' 10" × 9' 6". End of car over driving bogie.
Size and position of driver's compartment or compartments.	In engine compartment only.	In engine compartment only.
6. *For trailer purposes, are standard vehicles used, or has specially constructed stock been adopted?*	Special, baggage and mail.	No trailers.
Give particulars of weights, accommodation, and seating arrangements	Light weight 50 660 lb., mail 8 500 lb., bagg. 18 500 lb. Smoking compartment in motor car, 10 seats.	...
Is any provision made for smoking, either in motor cars or trailers.	...	Smoking provided for in motor car.
7. *Are rail motors fitted with standard buffers and couplings?*	Yes.	No.
Will the same answer apply to specially constructed trailers?	Yes.	...
8. *Braking methods.*	Westinghouse A. M. L.	Westinghouse air.
Continuous braking (specify the system):		
Screw brake	...	...
Lever brake.	Lindstrom lever and peacock staffless.	...
Steam brake	...	...
For each braking apparatus please state if it acts on all the wheels of the car or on part only.	All wheels.	All wheels.
What percentage of brake power is provided in the main braking apparatus?	100 % at 50 lb. per sq. in. cylinder pressure.	90 %
9. *Heating system of rail motors and trailers and how controlled.*	Hot water.	Hot water.
Lighting system for car, head, and tail lights.	Electric.	Electric.
10. *If the weight of R.M. is limited in any way by condition of track or bridges, please give:*		
Maximum permissible axle load.	No limitation.	No limitation.
Weight of rails per yard.		
Length of rails.		
Number of supports (sleepers-ties) for each rail length.		
11. *Approx. light weight of standard type vehicle, which most closely resembles the R.M. in respect to comfort, good riding and carrying capacity.*	114 000 lb.	Combination passenger-baggage 97 000 lb.

Minneapolis, St. Paul and Sault Ste. Marie.	New York, New Haven and Hartford.	Northern Pacific.	Reading.
175 H. P. petrol-elect. 10	250 H. P. petrol-elect. 11	600 H. P. petrol-elect. 12	600 H. P. petrol-elect. 13
End of car over driving bogies.	11' 2" × 9' 5". End of car over driving bogie.	18' 0" × 9' 2 1/2". At front of car.	16' 8" (av.) × 9' 3". End of car.
In engine compartment only.	In engine compartment and small cabin at opposite end.	In engine compartment only.	In engine compartment and small cabin at other end.
Standard.	Various standard vehicles.	All standard.	Both. Passenger cars only.
Light weight 87 750 lb. Express and mail.	80 000 lb. 104 seats.	Pass. types, weight from 90 000 lb. to 120 000 lb. — 68 to 84 seats.	Standard cars: 116 260 lb. — 78 seats. Special cars: 65 500 lb. — 73 seats.
Yes, in motor car.	Compartment for 20 smokers in motor car only.	...	Smoking provided for on motor car only.
No.	Three of these cars provided with standard draft gear and couplers.	Yes.	Light weight standard A. R. A. couplers.
...	...	Yes.	Yes.
Westinghouse.	Westinghouse straight air and automatic air.	Westinghouse. Auto air.	Westinghouse straight and automatic air.
...	...	Hand brakes fitted.	Standard hand brake.
...	...	...	...
...	...	...	...
All wheels.	All wheels.	All wheels.	...
60 %	110 % of light weight.	90 % of light weight.	100 %
Hot water.	Individual hot water or hot air heaters manually controlled.	Hot water, manual control.	Hot water or steam heat, coal or oil fired.
Electric.	Electric light from storage battery and charging equipment.	Electric.	Electric car and head lights. Oil marker lights.
No limitation.	No limitation.	No limitation.	No limitation.
Nothing similar.	...	145 000 lb.	116 260 lb.

Name of railway	**Southern Pacific.**	**Canadian National.**
Brief particulars of cars other than those listed below. *Type, horse-power and number*	Gas-electric: 175 H. P.—2 cars. 300 H. P.—6 cars. 400 H. P.—12 cars.	Storage battery: 100 H. P.—6 cars. Gas-mechanical: 85 H. P.—1 car. 125 H. P.—10 cars. Gas-electric: 120 H. P.—8 cars. 220 H. P.—1 car. Oil-electric: 200 H. P.—8 cars. 300 H. P.—18 cars.
Type of car 1	600 H. P. petrol-elect. 14	400 H. P. oil-elect. 15
1. *Number of 2-axle cars.*	...	...
» *3-axle cars.*	...	...
» *2-bogie (truck) cars*	5	...
» *articulated cars*	...	2
2. *Diagrams of rail motor cars (elevation and plan), preferably to scale or 1 : 100 for each class of car mentioned in (1) above. Following information should be given :*	All-steel.	...
Number of motor axles.	4	4
Number of coupled axles	Nil.	Nil.
Gauge of track	4' 8 1/2''	4' 8 1/2''
Total wheel-base	60' 3''	85' 10''
Distance between centres of bogie (truck) axles.	7' 9'' both bogies.	7' 4'' all three bogies.
Diameter of wheels	33''	36''
Length over buffers.	75' 5''	104'
Length of body	73'	102'
Internal width and height of compartments.	9' 6''×8' 0'' approx.	10' 4''×8' 0''
Type of journal bearings	Fafnir Melcher roller.	S. K. F.
3. *Weight of rail motor car unloaded*	...	188 000 lb. Front axles — 39 500 lb. Middle » — 24 500 lb. Rear » — 30 000 lb.
In service, fuelled complete (fuel, water, etc.), but without passengers, baggage or mails.	167 500 lb. Front axles — 49 425 lb. Rear » — 34 325 lb.	...
In service, fuelled complete, and with maximum load of passengers, baggage and mails	175 500 lb. approx.	206 000 lb.
In each of the above cases give distribution of weight on each axle.	...	...
Weight (light) of engine alone when it constitutes a separate chassis	Nil.	Nil.

Japanese Government.	Chosen Government (Korea).	Federated Malay States.	East Indian.
Steam : 2-bogie—16 cars.	Steam : Articulated—2 cars (narrow gauge). 100 H. P. (Sentinel)—2 cars (standard gauge). Petrol-mechanical : 24 H. P.—7 cars (narrow). 55 H. P.—4 cars (standard).	Nil.	Nil.
40 H. P. petrol-mech. 16	100 H. P. petrol-mech. 17	100 H. P. steam. 18	100 H. P. steam. 19
12	...	...	...
...	...	...	...
...	6	...	...
...	...	1	3
...	...	Sentinel.	Sentinel.
1	1	1	1
Nil.	Nil.	Nil.	Nil.
3' 6"	4' 8 1/2"	3' 6"	5' 6"
14' 9"	48' 10"	78' 4"	89' 2"
No bogies.	5' 11" each bogies.	6' 0" eng. and interm. bogies. 5' 6" trlg. bogie.	6' 6" both end bogies. 9' 0" interm. bogie.
34" (860 mm.)	34"	33 1/2"	30"
33'	63' 5"	95' 5 1/2"	103' 10"
29' 6"	58' 6"	91'	99' 10"
7' 10 1/2" × 6' 6 1/2"	8' 7" × 5' 10" approx.	8' 4 1/2 × 7' 6" approx.	8' 3 1/2" × 8' 0" approx.
...	S. K. F. roller.	Roller bearings.	Plain bearings — 2 units. Roller (S. K. F.)— 1 unit.
Not given.	...	84 224 lb. Eng. bogie 19 096 lb. Inter. » 12 096 lb. Trlg. » 10 920 lb.	82 568 lb. Nos. 1 and 2 axles 10 696 lb. No. 3 » 19 892 lb. No. 4 » 18 772 lb. Nos. 5 and 6 » 10 696 lb.
...	52 800 lb.	93 184 lb. Eng. bogie — 21 112 lb. Inter. » — 14 224 lb. Trlg. » — 11 256 lb.	87 720 lb. Nos. 1 and 2 axl.—10 696 lb. No. 3 » —21 516 lb. No. 4 » —21 740 lb. Nos. 5 and 6 » —11 536 lb.
44 800 lb.	66 000 lb.	105 728 lb. Eng. bogie — 21 840 lb. Int. » — 17 136 lb. Trlg. » — 13 888 lb.	104 072 lb. Nos. 1 and 2 axl.—13 580 lb. No. 3 » —25 044 lb. No. 4 » —25 268 lb. Nos. 5 and 6 » —13 300 lb.
...	...	...	Axle arrangement : $\underset{\underbrace{0\quad 0}}{1\quad 2}\qquad\underset{\underbrace{0\quad 0}}{3\quad 4}\qquad\underset{\underbrace{0\quad 0}}{5\quad 6}$
Nil.	Nil.	Nil.	Nil.

Name of railway	**Southern Pacific.**	**Canadian National.**
Type of car 1	600 H. P. petrol-elect. 14	400 H. P. oil-elect. 15
4. *What classes are provided?*	One class.	One class.
Seating accommodation for each class (give diagram).	54 seats. (Above figure is for pass. car. Other arrangements are passenger baggage and baggage-mail).	121 to 124 seats.
Size and maximum load capacity of baggage compartment .		16' 6" × 10' 4"
Size and maximum load capacity of mail compartment .		...
5. *Size and position of engine compartment.* .	15' 10" × 9' 6". End of car.	17' 6" × 10' 4". End of car.
Size and position of driver's compartment or compartments .	In engine compartment and small cabin at opposite end.	In engine compartment only.
6. *For trailer purposes, are standard vehicles used, or has specially constructed stock been adopted?*	Not stated.	Both. Special vehicles have roller bearings.
Give particulars of weights, accommodation, and seating arrangements .	...	Weights vary from 40 000 to 96 000 lb.
Is any provision made for smoking, either in motor cars or trailers .	Smoking provided for in motor car, 12 seats.	Yes, in motor car 35 seats.
7. *Are rail motors fitted with standard buffers and couplings?*	Light weight standard contour couplers.	Standard couplings. No buffers.
Will the same answer apply to specially constructed trailers?	...	Yes.
8. *Braking methods.*	Westinghouse A. M. L.	Westinghouse air.
Continuous braking (specify the system):		
Screw brake	...	One at each end.
Lever brake.	Peacock staffless.	...
Steam brake	...	None.
For each braking apparatus please state if it acts on all the wheels of the car or on part only.	All wheels.	All wheels.
What percentage of brake power is provided in the main braking apparatus?	100 % at 60 lb. per sq. in. cylinder pressure.	84 1/2 % at 50 lb. per sq. in. cylinder pressure.
9. *Heating system of rail motors and trailers and how controlled* .	Steam heating, oil fired.	Hot water, coal fire, self feeding.
Lighting system for car, head, and tail lights.	Electric (32-volt).	All-electric.
10. *If the weight of R.M. is limited in any way by condition of track or bridges, please give:*	No limitation.	No limitation.
Maximum permissible axle load.		
Weight of rails per yard.		
Length of rails.		
Number of supports (sleepers-ties) for each rail length.		
11. *Approx. light weight of standard type vehicle, which most closely resembles the R.M. in respect to comfort, good riding and carrying capacity.*	...	90 000 lb.

Japanese Government.	Chosen Government. (Korea).	Federated Malay States.	East Indian.
40 H. P. petrol-mech. 16	100 H. P. petrol-mech. 17	100 H. P. steam. 18	100 H. P. steam. 19
Third class only.	Third class only.	Two classes.	Two classes.
34 seats.	90 seats.	2nd class-12 seats. 3rd class-84 seats.	1st class — 10 seats. 3rd class — 90 seats.
5' 4"×7' 10 1/2"	Two compartments each 4' 0"×3' 9" approx.	4' 2"×8' 4 1/2"	7' 7"×8' 3 1/2" approx.
...	...	...	...
None — engine underneath floor.	None. Located beneath floor near centre.	9' ×8' 4 1/2" approx. End of car houses boiler-eng. under floor.	11' 3"×9' 0" approx. In centre over intermediate bogie.
One at each end. 3' 1 1/2"×2' 7".	Cabin at each end. 4' 0"×3' 9" approx.	In engine compt. and cabin 4' 0"×8' 4 1/2" at opposite end.	Cabin at each end. 3' 6"×8' 3 1/2" approx.
Not given.	No trailers.	No trailers.	No trailers.
...	...	...	...
...	...	No restriction on smoking.	Not stated.
Yes.	No.	Yes.	Couplers standard buffers special.
...	...	...	...
Air.	Westinghouse air.	Automatic vacuum.	Vacuum brake.
...	Hand brake provided.	...	Clasp brake on intermediate.
Yes.	...	Hand brake acting on engine bogie only.	Single on other bogies.
...	...	...	...
All wheels.	All wheels.	...	All wheels.
Not given.	100 % of light weight.	Not given.	Not given.
Hot water from water jacket.	Exhaust gas and circulating water heating.	None.	None.
Electric, from storage battery.	Electric.	Electric, from axle generator.	Electric throughout except buffer lights, which are oil.
No limitation.	Axle load 12.75 tons. Rails 74 lb. per yd. 33 ft. Sleepers 17 per length (standard gauge).	Yes. Axle load 10 tons. Rails 60 lb. per yd, 30' long. Sleepers, 15 per length.	No limitation. Axle load 15 to 22.5 tons. Rails 65 to 90 lb per yd, 25' to 41' load. Sleepers N+1 to N+3 (N=Length of rail in yards).
...	...	Nothing comparable.	80 640 lb.

Name of railway	**Nigerian.**	**Sudan Government.**
Brief particulars of cars other than those listed below. *Type, horse-power and number*	Steam: 2-bogie—100 H. P. 1 car.	Nil.
Type of car 1	100 H. P. steam. 20	100 H. P. steam. 21
1. *Number of 2-axle cars.*	...	...
» *3-axle cars.*	...	...
» *2-bogie (truck) cars*	...	2
» *articulated cars*	1	...
2. *Diagrams of rail motor cars (elevation and plan), preferably to scale of 1 : 100 for each class of car mentioned in (1) above.*		
Following information should be given :	Sentinel.	Clayton.
Number of motor axles.	1	1 (Jackshaft).
Number of coupled axles	Nil.	2
Gauge of track	3' 6"	3' 6"
Total wheel-base	...	46' 0"
Distance between centres of bogie (truck) axles.	5' 6" and 6' 6"	7' 0" driving 6' 0" trailing.
Diameter of wheels	30"	33 1/2" and 42"
Length over buffers.	...	55' 5 1/2"
Length of body	62' 5"	47' 2 1/2"
Internal width and height of compartments.	8' 8 1/2" × (?)	8' 0" × 8' 0"
Type of journal bearings	...	Brasses with inserts.
3. *Weight of rail motor car unloaded*	Not given.	58 800 lb.
In service, fuelled complete (fuel, water, etc.), but without passengers, baggage or mails.	...	66 136 lb.
In service, fuelled complete, and with maximum load of passengers, baggage and mails.	...	...
In each of the above cases give distribution of weight on each axle.	...	...
Weight (light) of engine alone when it constitutes a separate chassis.	...	Not given.
4. *What classes are provided?*	Not given.	Two classes.
Seating accommodation for each class (give diagram).	...	2nd class — 12 seats. 4th class — 39 seats.
Size and maximum load capacity of baggage compartment.	...	3' 11" × 8' 0" 4 500 lb.
Size and maximum load capacity of mail compartment.	...	...

South African.	New Zealand Government.	Western Australian Government.	Tasmanian Government.
Steam: 3 axles — 2 cars. Petrol-mechanical: 2 axles — 2 cars (2' 0"). 3 axles — 9 cars (3' 6" gauge).	Storage battery: 120 H. P. — 1 car.	Petrol-mechanical: 2 axles, 40 H. P.— 2 cars.	Petrol-mechanical: 2-4-2 type — 5 cars. 2-bogie, 75 H. P.— 2 cars.
60 H. P. petrol-mech. [illegible]	100 H. P. steam. 23	100 H. P. steam. 24	100 H. P. petrol-mech. [illegible]
...	...	...	...
6	...	...	...
...	1	1	2
...	...	...	...
...	Clayton.	Sentinel.	...
1	...	1	[illegible]
Nil.	2	...	Nil.
3' 6"	3' 6"	3' 6"	3' 6"
25' 1 1/2"	48' 3"	36' 10"	33'
4' 3" leading-bogie.	7' 0" driving. 5' 6" trailing.	6' 6" driving. 6' 0" trailing.	5' 0" both bogies.
34" dvg. 24 1/2" bogie.	42" and 30 1/4"	31 1/2"	30"
...	57' 6"	64' 1 1/4"	...
37'	49' 8"	58' 6"	42' 6"
8' 9"×7' 0" approx.	7' 8"×7' 10"	8' 2 3/8"×8' 0"	8' 7"×7' 4"
Metalled brasses—driver. Roller—bogie.	Roller.	Plain brasses.	Timken roller—motor bogie. Loco. type—trailer bogie.
29 350 lb. Bogie axles 7 740 lb. Dvg. » 13 870 lb.	39 200 lb.	64 288 lb.	...
...	...	71 008 lb. Dvg. 21 112 lb. Tlg. 14 392 lb.	32 000 lb.
36 850 lb. Bogie axles — 9 290 lb. Dvg. » — 18 270 lb.	54 880 lb.	82 768 lb. Dvg. 23 744 lb. Tlg. 17 640 lb.	42 300 lb.
...	...	...	...
Nil.	Not given.	Nil.	Nil-
Two classes. 1st (European)— 24 seats. 2nd (native) — 15 seats.	2nd class only. 56 seats.	2nd class only. 56 seats.	Two classes. 1st class — 21 seats. 2nd class — 23 seats.
6'×8' 9'	...	9' 1 1/2×8' 2 3/8" 2 800 lb.	...
...	...	...	...

Name of railway	**Nigerian.**	**Sudan Government.**
Type of car 1	100 H. P. steam. 20	100 H. P. steam. 21
5. *Size and position of engine compartment.*	...	8' 1 1/2" × 8' 0". At front.
Size and position of driver's compartment or compartments.	...	In engine compartment and cabin at opposite end—3' 0" × 8' 0".
6. *For trailer purposes, are standard vehicles used, or has specially constructed stock been adopted?*	No trailers.	No trailers.
Give particulars of weights, accommodation, and seating arrangements.	...	...
Is any provision made for smoking, either in motor cars on trailers.	No regulation.	No restriction on smoking.
7. *Are rail motors fitted with standard buffers and couplings?*	...	Yes.
Will the same answer apply to specially constructed trailers?	...	...
8. *Braking methods.*	Not given.	Vacuum.
Continuous braking (specify the system):		
Screw brake	...	Yes. At each end. Operates on nearest bogie only.
Lever brake.	...	...
Steam brake	...	...
For each braking apparatus please state if it acts on all the wheels of the car or on part only.	...	All wheels.
What percentage of brake power is provided in the main braking apparatus?	...	Not given.
9. *Heating system of rail motors and trailers and how controlled*	...	None.
Lighting system for car, head, and tail lights.	...	Electric, from axle generator.
10. *If the weight of R.M. is limited in any way by condition of track or bridges, please give:*		
Maximum permissible axle load. *Weight of rails per yard.* *Length of rails.* *Number of supports (sleepers-ties) for each rail length.*	...	Axle load 11 tons for rails 50 lb. per yd, 30 ft. Sleepers, 12 per length.
11. *Approx. light weight of standard type vehicle, which most closely resembles the R.M. in respect to comfort, good riding and carrying capacity.*	...	...

South African.	**New Zealand Government.**	**Western Australian Government.**	**Tasmanian Government.**
60 H. P. petrol-mech. ■	100 H. P. steam. ■	100 H. P. steam. ■	100 H. P. petrol-mech. 25
6' 6 1/2"×8' 9". In front over leading bogie.	10' 6"×7' 8". At end pivotted on engine bogie.	9' 9"×8' 2 3/8". In front over dvg. bogie. Houses boiler; engine under car.	None. Located beneath floor in centre.
In engine compartment only.	4' 0"×7' 8" At engine end only.	In eng. compt. Cabin at opposite end. 4'0"×8' 2 3/8".	Cabin at each end. 2' 4"×3' 0" approx.
No trailers	No trailers.	Both. Standard (3 in all), light weight 48 160 lb. Seats 82, 2nd class. Special (1 only). Light. wgt. 6 384 lb. Seats 20, 2nd class.	Only one trailer — special Timken roller bearings. Pass. type loaded wgt. 24 276 lb., 41 seats.
...	...		Baggage compt. 8'×4' 0" approx.
Smoking apparently permitted.	Yes, in motor car.	Yes, both in motor and trailers.	Yes.
Buffers not fitted. Provision for emergency coupling only.	Yes.	Yes.	No.
...	...	Yes.	No.
Westinghouse air on drivers only.	Steam.	Vacuum.	Westinghouse air.
Worm and quadrant hand brake on bogie wheels only.	Yes.	Yes.	Yes.
...	...	...	...
...	Yes.	...	...
...	All wheels.	All wheels.	All wheels.
100 % with air and hand brakes together.	...	67 % on driving and 64 % on trailing.	Not given.
None.	None.	None.	None.
Elec. car lights from axle generator. Head and tail from ignition system.	Electric, from axle generator.	Electric, from axle generator.	Electric.
No limitation.	No limitation.	No limitation.	No limitation. Axle load, 13 tons. Rails, 63 lb. per yd, 40 ft. On main lines.
39 000 lb.	...	48 160 lb.	29 120 lb.

Name of railway	**New South Wales Government.**	**New York Central.**
Brief particulars of cars other than those listed below. *Type, horse-power and number*	Nil.	Gas-mechanical: 175 H. P. — 10 cars. Gas-electric: 250 H. P. — 17 cars. (All roller bearings).
Type of car 1	100 H. P. petrol-mech. 26	500 H. P. gas-elec. 27
1. *Number of 2-axle cars.*	...	...
» *3-axle cars.*	...	...
» *2-bogie (truck) cars*	37	6
» *articulated cars*	...	...
2. *Diagrams of rail motor cars (elevation and plan), preferably to scale or 1 : 100 for each class of car mentioned in (1) above. Following information should be given :*	Steel underframe. Wood body.	...
Number of motor axles.	1	4
Number of coupled axles	Nil.	...
Gauge of track	4' 8 1/2"	4' 8 1/2"
Total wheel-base	33' 6"	61' 4 1/2"
Distance between centres of bogie (truck) axles.	5' 0" each bogie*.	8' 0" front. — 7' 9" rear.
Diameter of wheels	25" and 32 1/2"	33"
Length over buffers.	44' 8"	75' 6 3/4"
Length of body	42'	73' 0"
Internal width and height of compartments.	8' 10" × 7' 3 1/2"	9' 6" × 9' 2"
Type of journal bearings	Plain brasses. (1 car S. K. F. roller)	A. R. A. brass.
3. *Weight of rail motor car unloaded*	32 900 lb.	156 000 lb.
In service, fuelled complete (fuel, water, etc.), but without passengers, baggage or mails.	34 000 lb. Ldg. axle 8 675 lb. Dvg. » 9 125 lb. Each tlg. axle 8 100 lb.	160 000 lb.
In service, fuelled complete, and with maximum load of passengers, baggage and mails.	42 900 lb.	185 000 lb. Front axles — 52 500 lb. Rear » — 40 000 lb.
In each of the above cases give distribution of weight on each axle.	...	...
Weight (light) of engine alone when it constitutes a separate chassis.	Nil.	Nil.
4. *What classes are provided?*	Two classes.	One class only.
Seating accommodation for each class (give diagram).	1st class — 21 seats. 2nd class — 24 seats.	31 seats.
Size and maximum load capacity of baggage compartment.	9' 4 3/4" × 8' 10" 4 000 lb.	22' 4" × 9' 6" 15 000 lb.
Size and maximum load capacity of mail compartment.	...	17' 1" × 9' 6" 5 000 lb.

* 5 cars have bogies with 5' 6" centres.

Name of railway	New South Wales Government.	New York Central.
5. Size and position of engine compartment.	None. Located beneath floor in centre.	15' 10" × 9' 6" at front.
Size and position of driver's compartment or compartments.	Cabin at each end 3' 10" × 3' 1 1/2".	In engine compt. only.
6. For trailer purposes, are standard vehicles used, or has specially constructed stock been adopted?	Specially constructed. Two types. Pass. — Weight 25 750 lgt., 40 750 loaded. Seats: 12—1st class, 20—2nd class.	Standard. Light weight 137 000 lb. 82 seats. Also special light wgt.
Give particulars of weights, accommodation, and seating arrangements.	Baggage—weight 8 175 lb. lgt.—11 200 lb. loaded.	43 000 lb. 60 seats.
Is any provision made for smoking, either in motor cars on trailers.	In trailer only.	In rail motor car.
7. Are rail motors fitted with standard buffers and couplings?	No.	No.
Will the same answer apply to specially constructed trailers?	Yes.	Yes.
8. Braking methods. Continuous braking (specify the system):	Westinghouse St. air.	Westinghouse A. M. L.
Screw brake	Geared chain hand brake (operates on nearest bogie only). No braking on driving wheels.	...
Lever brake.	...	...
Steam brake	...	...
For each braking apparatus please state if it acts on all the wheels of the car or on part only.	On three pairs of wheels only.	All wheels.
What percentage of brake power is provided in the main braking apparatus?	75 % light weight.	100 % light weight.
9. Heating system of rail motors and trailers and how controlled.	None.	Hot water, manual control.
Lighting system for car, head, and tail lights.	Elec., car and head lights. Oil, tail lights.	Electric.
10. If the weight of R.M. is limited in any way by condition of track or bridges, please give:		
Maximum permissible axle load.	No limitation.	No limitation.
Weight of rails per yard.		
Length of rails.		
Number of supports (sleepers-ties) for each rail length.		
11. Approx. light weight of standard type vehicle, which most closely resembles the R.M. in respect to comfort, good riding and carrying capacity.	50 000 lb.	107 000 lb.

Name of railway	**Baltimore and Ohio.**	**Boston and Maine.**
Type of car	600 H. P. gas-electric.	275 H. P. gas-electric.
1	2	3
1. *Steam boiler, particulars and description*	...	...
2. *Engine*	Two Stirling Viking.	Winton 120.
Number of cylinders	6 each.	6
Bore and stroke	7 1/2" × 9"	7 1/2" × 8 1/2"
Boiler pressure (for steam)	...	...
Mean effective pressure	...	90 lb. p. sq. in.
Two or four-cycle.	4-cycle.	4-cycle.
Rated horse-power	300 H. P. each.	275 H. P.
Brake H. P. at governed speed — r. p. m.	300 H. P. at 1 100 r. p. m.	275 H. P. at 1 050 r. p. m.
Maximum B. H. P. at — r. p. m.	...	...
Fuel consumption — lb. per B. H. P.-hour at :		
a) *Normal output*	Not given.	Not known.
b) *Maximum output*	...	...
Fuel :		
a) *Physical properties*	Gasoline.	Standard American gas.
b) *Specific gravity*	...	0.745
c) *Viscosity*	...	...
d) *Distillation ranges, etc.*	U. S. Government Spec. 2 D. Tech. paper 323 B.	First drop 102° F. 50 % 261° F. End point 394° F. 95 % recovery.
e) *Calorific value (B. T. U. per lb. for solids and liquids; B. T. U. per cubic foot for gas).*	...	Not given
Lubrication system	Pressure.	Pressure-dry sump.
Lubricating oil, physical properties	National 2-B, Sp. gr. 0.915; Flash 465° F; Visc. at 210°=91 sec. Say.	Mobiloil B or equivalent.
Auxiliaries :		
a) *(I) fuel, (II) oil strainers :*	(I) None. (II) Yes.	(I) Yes. (II) No.
b) *Air cleaners*	Yes.	No.
c) *Carburettors or fuel injection*	Zenith carburettor.	Zenith U. S. 52 carburettor.
d) *Ignition*	Scintilla magneto.	Bosch magneto.
e) *Cooling system*	Water, roof radiators.	Water, with fan.
f) *Clutch, etc.*	None.	None.

echnical.

Central of Georgia.	Chesapeake and Ohio.	Great Northern.	Gulf Coast and Internat. Great Northern.
90 H. P. gas-mechanical. 4	275 H. P. gas-electric. 5	400 H. P. oil-electric. 6	220 H. P. gas-electric. 7
...	...	...	...
Continental 14.	Hall Scott 350.	...	Winton.
6	6	6	6
4 1/2"×5 3/4"	7 1/2"×9"	9"×12"	7 1/4×8"
...	...	...	...
...	...	...	...
4-cycle.	4-cycle.	4-cycle.	4-cycle.
92 H. P.	275 H. P.	400 H. P.	220 H. P.
92 H. P. at 1 500 r. p. m.	275 H. P. at 1 050 r. p. m.	No tests.	225 H. P. at 1 050 r. p. m.
102 H. P. at 1 800 r. p. m.	300 H. P. au 1 100 r. p. m.	...	...
Not given.	Not given.	No tests.	Not given.
...	...	...	...
Gasoline 0.753 gravity.	High anti-knock rating, preferably cracked.	Flash 250° F. Fire 280 F.°	...
0.753	...	0.874 at 60° F.	
...	...	57 sec. Say. at 70° F.	...
Not given.	First drop 104° F. 50 % 275° F. End point 410° F. 95 % recovery.	...	Not given.
Not given.	...	Not given.	...
Pressure.	Pressure and splash.	Pressure lubrication	Pressure.
...	470° F. flash, 45° F. pour points, 0.905 gravity. Visc. : 104° F. = 960 secs. Say. 140° F. = 367 » » 210° F.=97-101 » »	470° F. fire, 10° F. pour point, 0.8% carbon, visc. at 210° F. = 90-95 secs. Say.	Not given.
(I) ... (II) ...	(I) — (II) Felt lined.	Fine mesh screens.	(I) Yes. (II) Yes.
...	None.	...	None.
Carburettor.	Zenith carburettors.	Solid injection.	Carburettors.
Magneto.	Magneto, Bosch dual.	Compression ignition.	Magneto.
Water.	Water with radiators and fan.	Water cooling with motor driven fans.	Water, radiators and fans.
Multiple dry disc.	None.	None.	None.

Name of railway	**Baltimore and Ohio.**	**Boston and Maine.**
Type of car 1	600 H. P. gas-electric. 2	275 H. P. gas-electric. 3
3. *Gas producer, particulars and description, and method of working; including scrubbers, gas cleaners, starting blower, etc.*	...	...
4. *Electric accumulator :*		
Acid or alkaline.	...	...
Number, type, size and capacity of cells.		
Weight of battery.		
Normal charging rate.		
Maximum charging rate.		
Maximum discharge rate, etc.		
5. *Electric generator (petrol or oil-electric) :*		
Rating.	210 kw.	180 kw.
System of field wiring	Shunt.	Differential field.
Self or separately excited.	Separately excited.	Separately excited from Integral exciter.
Attachment to engine, etc.	Flexibly coupled.	Steel discs.
6. *Gear box :*		
Description and arrangement	...	...
Drawing if available		
Gear ratio		
7. *Final drive—Mechanical transmission :*		
Description and arrangement	...	...
Drawing if available	...	...
Gear ratio	...	...
8. *Motors—Electric transmission :*		
Number and rating	Four 250 H. P.	Two 150 H. P.
System of suspension	Nose.	Nose.
Direct, spur gear, bevel gear, or worm drive.	Spur.	Spur.
Gear ratio, etc.	55 : 24	57 : 22
9. *Control—Mechanical transmission :*		
Single end or double end control	Single.	Double.
Arrangement for reverse running		
Full description of the control system	...	Duplicate of front end.
Equipment of control cabin remote from engine.		

Central of Georgia.	Chesapeake and Ohio.	Great Northern.	Gulf Coast and Internat. Great Northern.
90 H. P. gas-mechanical. 4	275 H. P. gas-electric. 5	400 H. P. oil-electric. 6	220 H. P. gas-electric. 7
...	...	...	...
...	...	...	...
...	185 kw.	West. type 447 D. 8, 550 volts.	G. E. 600 v., 160 kw.
...	Compound.	Compound.	Compound.
...	Separately excited from Integral exciter.	Separately excited from aux. unit.	Separately.
...	Both direct connected and flexibly coupled.	Through metal discs.	Direct.
Not given.	..	...	...
Not given.	...	...	...
...	...	...	...
...	...	...	...
...	Two 150 H. P.	West. 585 A. 2. Two 525 v., 245 H. P.	G. E. Two 600 v., 90 H. P.
...	Nose suspension.	Nose suspension.	Nose suspension.
...	Spur.	Spur.	Spur.
...	52: 19	56: 20	57: 18
Not given.	Single.	Single.	Single.
...	...	...	...

Name of railway	**Baltimore and Ohio.**	**Boston and Maine.**
Type of car	600 H. P. gas-electric.	275 H. P. gas-electric.
1	2	3
10. *Control—Electric transmission :*		
Full description of system, of control adopted, whether engine speed, generator field, motor connection, rheostatic, or a combination of one or more of the above.	Torque control. (See Gt. Northern).	Differential winding in exciter field through which main current passes, cutting down voltage as load increases.
Is provision made for multiple unit control ?	...	No.
11. *Auxiliary equipment :*		
Provision for starting engine	Electric through main generator.	Electric and air.
Power for train lighting, heating, etc. . . .	Battery charged from exciter. Hot water.	Battery charged from exciter.
Power for continuous brake system	Not given.	Motor-driven 20-c. ft. compressor.
Electric accumulator (for car types other than battery cars).	16 lead cells, 300 A. H. capacity.	16 Exide MVAH 13 cells.
12. *Amount of fuel and water which can be carried on the rail motor :*		
Provision made for supply of fuel and water or for recharging accumulators :	415 Imp. gals. petrol. 310 » water.	210 Imp. gals. petrol.
a) *At depot stations*	Underground tanks and pumps.	Underground tanks and pumps.
b) *En route*.	—	...
13. *Safety precautions taken in the event of :* *Fire*.	Fire extinguisher.	Water and tetrachloride extinguishers.
Disablement en route	...	...
14. *Information regarding most difficult service worked with rail cars.*	M. and K. Junction to Morgantown; Heavy grades approximating 1.5 % for 12 miles in one direction and 15 miles in other direction. (**Note:** Grades shown on diagrams do not agree with those calculated from elevations and distances.)	...
...	Specifications supplied.	...

Central of Georgia.	Chesapeake and Ohio.	Great Northern.	Gulf Coast and Internat. Great Northern.
90 H. P. gas-mechanical.	275 H. P. gas-electric. 5	400 H. P. oil-electric.	220 H. P. gas-electric. 7
...	3 cars, torque control (Westinghouse). 3 cars, differential field control (G. E.).	Torque control. A torque (voltage) relay actuated by auxiliary generator voltage weakens or strengthens the generator shunt field when H. P. reqd. to drive generator is greater or less than engine can deliver.	G. E. K. 76. Generator field (differential).
...	No.	No.	No.
Not given.	None (?).	Air and electric.	Air and electric.
...	Generator and batteries.	Auxiliary generator.	Generator.
...		Hot water boiler.	
	Motor-driven compressor.	Motor-driven 35-cub. ft. compressor.	Motor-driven compressor.
...	...	None.	Yes.
42 Imp. gals. petrol.	330 Imp. gals. petrol. 83 » » water.	500 Imp. gals. petrol.	167 Imp. gals. petrol.
No particulars.	Fuel tanks and pumps.	Fuel storage tanks.	None (?)
None.	None.	...	...
Pyrene extinguishers.	Foamite extinguishers.	Shut off fuel, 2 or 3 fire extinguishers.	...
...	...	...	...
...	...	Two 400 H. P. petrol-electric cars each handle 2 trailers weighing loaded 137 500 lb. and 101 800 lb. Weight of train 377 300 lb. One train does 10 1/2 miles in 30 mins., including 1 1/2 miles of 1.5 to 1.65% grade and 3 miles of 0.5 to 0.64 % grade. Speed on maximum grade is about 12 m. p. h.	...
...	...	No detailed specifications supplied to builders.	...

Name of railway	**Missouri-Pacific.**	**Missouri-Kansas and Texas.**
Type of car	220 H. P. gas-electric.	200 H. P. gas-electric.
1	8	9
1. *Steam boiler, particulars and description*	...	...
2. *Engine*	E. M. type 106 A.	Winton.
Number of cylinders	[illegible]	6
Bore and stroke	7 1/4" × 8"	7" × 8"
Boiler pressure (for steam)	...	...
Mean effective pressure	...	...
Two or four-cycle.	4-cycle.	4-cycle.
Rated horse-power	220 H. P. at 1 050 r. p. m.	200 H. P.
Brake H. P. at governed speed — r. p. m.	...	175 H. P. at 1 000 r. p. m.
Maximum B. H. P. at — r. p. m.	...	...
Fuel consumption — lb. per B. H. P.-hour at :		
a) *Normal output*	Not given.	Not given.
b) *Maximum output*	...	...
Fuel :		
a) *Physical properties*	Gasoline.	Gasoline.
b) *Specific gravity*	...	...
c) *Viscosity*	...	...
d) *Distillation ranges, etc.*	Not given.	Not given.
e) *Calorific value (B. T. U. per lb. for solids and liquids; B. T. U. per cubic foot for gas).*	...	...
Lubrication system	Pressure and splash.	Pressure.
Lubricating oil, physical properties	...	National 2—B. Visc. 210° = 105 secs. Say.
Auxiliaries :		
a) *(I) fuel, (II) oil strainers*	(I) Yes. (II) —	(I) — (II) Stromberg.
b) *Air cleaners*	...	...
c) *Carburettors or fuel injection*	Stromberg carburettor.	Zenith U. S. 52 carburettor.
d) *Ignition*	Dual magnetos.	Bosch Z. R. 6 magneto.
e) *Cooling system*	Water, front radiators and fans.	Water with roof and front radiators.
f) *Clutch, etc.*	None.	None.

Minneapolis, St. Paul and Sault Ste. Marie.	**New York, New Haven and Hartford.**	**Northern Pacific.**	**Reading.**
175 H. P. gas-electric. 10	250 H. P. gas-electric. 11	600 H. P. gas-electric. 12	600 H. P. gas-electric. 13
...	...	...	...
...	Winton.	Two Winton No. 146 D.	Two Hall Scott 350.
6	6	6 each.	6 each.
7"×8"	7 1/4"×8"	8"×10"	7 1/2"×9"
...	...	...	...
...	...	...	91 lb. p. sq. in.
4-cycle.	4-cycle.	4-cycle.	4-cycle.
175 H. P.	250 H. P.	300 H. P.	300 H. P.
175 H. P. at 900 r. p. m.	250 H. P. at 1 100 r. p. m.	300 H. P. at 900 r. p. m.	300 H. P. at 1 100 r. p. m.
...	...	312 H. P.	330 H. P. at 1 100 r. p. m.
No record.	Not given.	...	0.65 lb.
...	...	...	0.65 lb.
Gasoline.	Vapour tension not greater than 10 lb. p. sq. in.	Vapour tension not greater than 10 lb. p. sq. in.	...
...	...	...	...
...	...	...	...
Not given.	10 % betwn. 122° F. and 176° F. 50 % over 284° F. End point 437° F. 95 % recovery.	First drop 131° F. 50 % over 284° F. End point 437° F. 95 % recovery.	First drop 98° F. 50 % over 256° F. End point 388 F. 95° recovery.
No record.	Not given.	Not given.	20 500 B. T. U. per lb.
Pressure lubrication.	Pressure.	Pressure lubrication.	Pressure.
Not given.	Sp. gr. at 60° 0.899. Flash 490° F. Pour 10° F. Visc. at 210° F. = 103 secs. Say.	Standard oil special heavy polarine. 140° F. = 353 secs. Say. 180° F. = 150 » » 220° F. = 79 » »	Three grades; Flash 425° F.; Pour 35° F. Visc. at 210° F. = 65, 75 and 100 secs. Say. Sp. gr. about 0.88
(I) Yes. (II) Yes.	(I) Yes. (II) Yes.	(I) Yes. (II) Yes.	(I) Yes. (II) Yes.
No.	...	None.	Yes.
Carburettor.	Carburettors.	Carburettors.	Carburettor.
Magneto.	Magneto usually, some battery.	Battery.	Spark.
Water.	Water, with radiators and fans.	Water cooling, roof radiators.	Water with radiators and fans.
None.	None.	None.	None.

Name of railway	**Missouri-Pacific.**	**Missouri-Kansas and Texas.**
Type of car	220 H. P. gas-electric.	200 H. P. gas-electric.
1	[illegible]	9
3. *Gas producer, particulars and description, and method of working; including scrubbers, gas cleaners, starting blower, etc.*	...	...
4. *Electric accumulator :*		
Acid or alkaline.	...	...
Number, type, size and capacity of cells.		
Weight of battery.		
Normal charging rate.		
Maximum charging rate.		
Maximum discharge, rate, etc.		
5. *Electric generator (petrol or oil-electric):*	G. E.	Multiple commutating pole.
Rating.	700 v., 160 kw.	700 volts.
System of field wiring	...	...
Self or separately excited.	Separately from 1 1/2 kw. Integral exciter.	Separately.
Attachment to engine, etc.	Direct.	Direct.
6. *Gear box :*		
Description and arrangement	...	...
Drawing if available		
Gear ratio		
7. *Final drive—Mechanical transmission :*		
Description and arrangement	...	...
Drawing if available	...	...
Gear ratio	...	...
8. *Motors—Electric transmission :*	G. E. 240 E.	G. E. 240 E.
Number and rating	Two 600 v., 110 H. P.	Two 600-volt.
System of suspension	...	Bar (nose) suspension.
Direct, spur gear, bevel gear, or worm drive.	...	Spur.
Gear ratio, etc.	...	57 : 18
9. *Control—Mechanical transmission :*		
Single end or double end control	Single-end.	Single.
Arrangement for reverse running	...	...
Full description of the control system	...	...
Equipment of control cabin remote from engine.	...	...

Minneapolis, St. Paul and Sault Ste. Marie.	New York, New Haven and Hartford.	Northern Pacific.	Reading.
175 H. P. gas-electric. 10	250 H. P. gas-electric. 11	600 P. H. gas-electric. 12	600 P. H. gas-electric. 13
...	...	...	...
...	...	...	...
...	...	W. E. and M. Co. 2 type 182.	...
100 kw.	160 kw.	...	210 kw.
...	Shunt.	Compound	Compound.
Separately.	Separately.	Separately.	Separately.
Direct.	Flexibly coupled.	Direct connected.	Fibre discs.
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
Two 75-H. P.	Two 140-H. P.	Four 150-H. P.	Four 150-H. P.
Nose.	Axle hung.	Spring cushioned on bolster brackets.	Nose.
Spur.	Helical gear.	Spur.	Spur.
57: 18	58: 19	52: 19	52: 19
...	Double-end.	Single.	Double.
...	...	...	...
...	Duplicate of front end.	...	Duplicate of front end.
...	...	...	...

Name of railway	**Missouri-Pacific.**	**Missouri-Kansas and Texas.**
Type of car 1	220 H. P. gas-electric. 8	200 H. P. gas-electric. 9
10. *Control-Electric transmission :* *Full description of system of control adopted, whether engine speed, generator field, motor connection, rheostatic, or a combination of one or more of the above.*	Generator field and motor connection.	Engine speed and motor connection.
Is provision made for multiple unit control ?	No.	No.
11. *Auxiliary equipment :* *Provision for starting engine*	Electric, air and hand.	Hand, air and electric.
Power for train lighting, heating, etc. . . .	Battery from exciter Hot water (Vapor 557).	Battery charged by exciter.
Power for continuous brake system	C. P. 127 A motor-driven compressor 600 v., 20 cu. ft. per min.	Motor-driven compressor.
Electric accumulator (for car types other than battery cars).	Edison 16 cell, 32 v., 150 A. H. Cap.	Not given.
12. *Amount of fuel and water which can be carried on the rail motor :*	167 Imp. gals. petrol.	125 Imp. gals. petrol.
Provision made for supply of fuel and water or for recharging accumulators : a) *At depot stations*	Terminals only.	At running sheds.
b) *En route.*	...	...
13. *Safety precautions taken in the event of :* *Fire.*	Fire extinguishers.	2 Pyrene extinguishers.
Disablement en route	...	None.
14. *Information regarding most difficult service worked with rail cars.*	...	...
...	...	...

Minneapolis, St. Paul and Sault Ste. Marie.	New York, New Haven and Hartford.	Northern Pacific.	Reading.
175 H. P. gas-electric. 10	250 H. P. gas-electric. 11	600 P. H. gas-electric. 12	600 P. H. gas-electric. 13
Engine speed and motor connection.	Engine speed and motor connection.	Engine speed, generator field and motor connection.	Not clearly stated.
No.	No.	No.	Yes.
Hand and air.	Either starter motor, or through main generator.	Hand, air or electric.	Either starter motor or through main generator.
Battery.	Battery with charging equipment.	Petrol-driven generator 36-v., 2 000 w., 1 350 r. p. m.	Battery charged from main gen. or aux. generator.
		Hot water (Vapor 557).	
...	Motor-driven compressor.	Motor-driven 50-cub. ft. compressor.	Motor-driven compressor.
32 volts, 150 amps.	Not given.	16 Exide M.V.A.H. 21 cells, 356 A. H. capacity (8 hr.).	16 cells, 13 plate 32 v. Max. discharge 350 A. Normal charge rate 20 A.
366 Imp. gals. petrol.	133 Imp. gals. petrol. 54 Imp. gals. water.	470 Imp. gals. petrol. 130 Imp. gals. water.	415 Imp. gals. petrol. 50-60 gals. water.
None.	Provision made where time is available.	None.	At home stations.
...	...	...	...
Fire extinguishers.	Fire extinguisher.	Three 2-gal. extinguishers	4 extinguishers.
...	...	None.	No special.
Regular trip of 250-H. P. motor with 80 000-lb. trailer on grade of 1 mile of 2.2 % series connection used for motors.	...	Trip between Helena and Garrison operated by 300-H. P. car. Slight falling grade for 3 1/2 miles, then 17 miles on avge. grade of 1.86 % inc., 10 miles of 2.2 %, then falling grade (0.86 %) for 30 miles. — Avg. speed throughout 26.5 m. p. h. On 2.2 % grade 16 m. p. h. Avg. elevation 4 800 ft. causing loss of engine power of 17 %. Full output of eng. required. No trailer hauled; car weight (loaded) 153 000 lb.	Trip between Trenton and Bound Brook, which includes 1 mile of 1.1 % grade. Average speed of 30 m.p.h. with one trailer. Train weight (loaded) 175 700 lb.
N. Y., N. H. and H. specifications used.	Electro-Motive Co. specifications used.	Specifications supplied for car construction.	Specifications supplied.

Name of railway	Southern Pacific.	Canadian National.
Type of car 1	600 H. P. gas-electric. 14	400 H. P. oil-electric. 15
1. *Steam boiler, particulars and description*	...	...
2. *Engine*	Two Hall Scott 350.	...
Number of cylinders	6 each.	8
Bore and stroke	7 1/2" × 9"	8 1/4" × 12"
Boiler pressure (for steam)	...	...
Mean effective pressure	...	82 lb. p. sq. in.
Two or four-cycle.	4-cycle.	4-cycle.
Rated horse-power	300 H. P.	400 H. P. at 700 r. p. m.
Brake H. P. at governed speed — r. p. m.	300 H. P. at 1 100 r. p. m.	...
Maximum B. H. P. at — r. p. m.	...	...
Fuel consumption — lb. per B. H. P.-hour at :		
a) *Normal output*	Not given	0.4 lb.
b) *Maximum output*	...	...
Fuel :		
a) *Physical properties*	Gasoline.	Flash 150° F. cold test. 50° F. below zero
b) *Specific gravity*	...	0.885
c) *Viscosity*	...	at 100° F. 60/70 secs. Say.
d) *Distillation ranges, etc.*	Not given.	Initial 400° F. 25 % 500° F.
e) *Calorific value (B. T. U. per lb. for solids and liquids; B. T. U. per cubic foot for gas).*	...	19 000 B. T. U. per lb.
Lubrication system	Pressure and splash.	Pressure.
Lubricating oil, physical properties	Not given.	Flash 400° F., cold 25° F., Viscosity at 100° F. = 600-700 secs. Say. at 212° F. = 70-75 secs.
Auxiliaries :		
a) *(I) fuel, (II) oil strainers*	...	Basket type 320 mesh. to in. Auto Klean 0.005" spacing.
b) *Air cleaners*	...	None.
c) *Carburettors or fuel injection*	Carburettors.	Solid injection.
d) *Ignition*	Magneto.	Compression ignition.
e) *Cooling system*	Water.	Water, natural ventilated radiators.
f) *Clutch, etc.*	None.	None.

Chosen Government.	Japanese Government.	Federated Malay States.	East Indian.
100 H. P. petrol-mech. 16	40 H. P. petrol. 17	100 H. P. steam. 18	100 H. P. steam. 19
...	...	Sentinel standard, coal fired.	Sentinel standard coal fired.
Waukesh. 6 R. B.	...	Sentinel standard horizontal.	Sentinel vertical.
6	4	6	[illegible]
5"×5 3/4"	...	6"×7" single acting.	5 3/4"×9"
...	...	300 lb. p. sq. in.	275 lb. p. sq. in.
...	...	...	...
4-cycle.	4-cycle.	...	...
...	40 H. P.	...	...
100 H. P. at 1 200 r. p. m.	43 H. P. at 1 200 r. p. m.	...	100 H. P. at 500 r. p. m.
120 H. P. at 1 600 r. p. m.	48 H. P. at 1 600 r. p. m.	120 H. P.	...
0.58 lb.	...	0.35 lb. per ton-mile.	0.35 lb. per ton-mile.
0.68 lb.	...	...	...
Not given.	Petrol.	Coal (local).	Coal.
...	Less than 0.75	...	...
...	...	...	...
...	...	...	...
...	...	9 600 B. T. U. per lb.	12 500 B. T. U. per lb.
Pressure.	Not given.	Detroit lubricator for cylinders. Pressure pump for shaft, etc.	Forced feed to cyls. splash to shaft.
Mobiloil.	...	...	Sp. gr. = 0.900. Closed flash 480° F., Visc. at 212° F. = 100 secs. Red.
(II) Strainer screen.	...	...	...
None.	...	...	...
Zenith carburettors.	Carburettor.	...	...
Battery and magneto.	Magneto.	...	...
Water.	Water.	...	...
Double plate dry.	Multiple plate.	...	...

Name of railway	**Southern Pacific.**	**Canadian National.**
Type of car 1	600 H. P. gas-electric. 14	400 H. P. oil-electric. 15
3. *Gas producer, particulars and description, and method of working; including scrubbers, gas cleaners, starting blower, etc.*	...	...
4. *Electric accumulator :*		
Acid or alkaline.	...	...
Number, type, size and capacity of cells.		
Weight of battery.		
Normal charging rate.		
Maximum charging rate.		
Maximum discharge, rate, etc.		
5. *Electric generator (petrol or oil-electric) :*	West. two type 181-A-4.	
Rating	500 v. 420 amp.	700 v. 198 kw.
System of field wiring	Compound.	Differential field.
Self or separately excited.	Separately from Integral exciters.	Separately excited.
Attachment to engine, etc.	Direct.	Direct.
6. *Gear box :*		
Description and arrangement	...	...
Drawing if available	...	...
Gear ratio	...	...
7. *Final drive—Mechanical transmission :*		
Description and arrangement	...	...
Drawing if available	...	...
Gear ratio	...	...
8. *Motors—Electric transmission :*	Westinghouse 559, E. 2	Westinghouse 548 C-8
Number and rating	Four 450 v. 240 A.	Four 600 v. 116 H. P.
System of suspension	Nose.	Nose.
Direct, spur gear, bevel gear, or worm drive.	Spur.	Helical.
Gear ratio, etc.	Not given.	65 : 24.

Chosen Government.	Japanese Government.	Federated Malay States.	East Indian.
100 H. P. petrol-mech. 16	40 H. P. petrol. 17	100 H. P. steam. 18	100 H. P. steam. 19
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	..	...
...	...	...	...
Selective gear type.	Four speed.	Sentinel standard.	...
Four speed.		One reduction (totally enclosed).	...
4.75, 4.0, 2.0 and direct.	4.66, 2.82, 1.65 and direct.	1.5 : 1	...
Reversing type crown wheels and pinion.	...	...	Chain drive (2 1/4 pitch roller) from engine to one axle.
...	...	Sentinel standard spur gearing from layshaft in gear box.	...
3.00 : 1	4.66	41 : 34	17 : 25
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...

Name of railway	**Southern Pacific.**	**Canadian National.**
Type of car 1	600 H. P. gas-electric. 14	400 H. P. oil-electric. 15
9. *Control—Mechanical transmission :*		
Single end or double end control	Double-end.	Double.
Arrangement for reverse running	...	...
Full description of the control system	...	...
Equipment of control cabin remote from engine.	Duplicate of front end.	Duplicate of front end.
10. *Control—Electric transmission :*		
Full description of system of control adopted, whether engine speed, generator field, motor connection, rheostatic, or a combination of one or more of the above.	Not stated. Probably West. torque control.	...
Is provision made for multiple unit control ?	Not stated.	No.
11. *Auxiliary equipment :*		
Provision for starting engine	Prob. air and electric.	Started by generator off battery.
Power for train lighting, heating, etc.	From battery (exciters 45 v., 80 amps.). Steam boiler 100 lb. p. sq. in.	From battery, charged by exciter.
Power for continuous brake system	2 D. H-25 W'house motor-driven compressors.	Motor-driven compressor.
Electric accumulator (for car types other than battery cars)	16 Exide M. V. A. H. 17 350 A. H. cap. (8 hr.).	64 Exide M. V. A., 17 Cells 272 A. H. cap. (64 volts).
12. *Amount of fuel and water which can be carried on the rail motor :*	500 Imp. gals. fuel. Not given.	150 Imp. gals. fuel. 240 » » water.
Provision made for supply of fuel and water or for recharging accumulators :		
a) *At depot stations*	Not stated.	Pumped from barrels by hand pump.
b) *En route*	...	...
13. *Safety precautions taken in the event of :*		
Fire	Not stated.	CO_2 extinguishers.
Disablement en route	...	...
14. *Information regarding most difficult service worked with rail cars.*	...	Most difficult run has maximum grade of 2 % for 3 miles. Average speed on this grade is 20 miles per hour. Average grade is 0.25 %.
...	Specifications supplied, for car construction.	Specifications supplied fo car construction.

Chosen Government.	Japanese Government.	Federated Malay States.	East Indian.
100 H. P. petrol-mech. 16	40 H. P. petrol. 17	100 H. P. steam. 18	100 H. P. steam. 19
Double.	Double.	Double.	Double.
Reversing final drive.	...	Reversing engine, standard Sentinel arrangement of regulator, etc.	Reversing engine regulator, etc. Control in each end cabin.
...	...		
Duplicate of front end.	...		
...	...	...	...
No.	...	No.	No.
24 v. — Starter motor.	12-volt Bosch starter motor.	Self starting.	Self starting.
Luce Neville generator, 24 volts.	...	Axle driven generator.	Axle driven generator.
Compressor.	...	Steam ejector.	Steam ejector.
...	...	...	...
30 Imp. gals. petrol.	35 Imp. gals. petrol. 29 gals. water.	2 800 lb. coal. 450 gals. water.	2 240 lb. coal. 300 gals. water.
Pump for petrol.	No details.	Loco. supplies.	Loco. supplies.
...	...	...	...
Minimax extinguishers.	...	Extinguishers.	Chemical extinguishers.
...	...	...	...
..	...	...	...
...	B. S. S. specifications.	...	Not available.

Name of railway	**Nigerian.**	**Sudan Government.**
Type of car 1	100 H. P. steam. 20	100 H. P. steam. 21
1. *Steam boiler, particulars and description*	Sentinel standard.	Clayton standard. 3' 0" dia. × 5' 10 — 5/8" high.
2. *Engine*	Sentinel standard.	Clayton standard.
Number of cylinders	...	2
Bore and stroke	...	7" × 10"
Boiler pressure (for steam)	...	275 lb. p. sq. in.
Mean effective pressure	...	...
Two or four-cycle.	...	...
Rated horse-power	...	...
Brake H. P. at governed speed — r. p. m.	...	Not given.
Maximum B. H. P. at — r. p. m.	...	...
Fuel consumption — lb. per B. H. P.-hour at :		
a) *Normal output*	Not given.	...
b) *Maximum output*	...	...
Fuel :		
a) *Physical properties*	...	Coal.
b) *Specific gravity*	...	...
c) *Viscosity*	...	...
d) *Distillation ranges, etc.*	...	...
e) *Calorific value (B. T. U. per lb. for solids and liquids; B. T. U. per cubic foot for gas).*	...	Not given.
Lubrication system	...	Splash for crank shaft.
Lubricating oil, physical properties	...	...
Auxiliaries :		
a) *(I) fuel, (II) oil strainers*	...	...
b) *Air cleaners*	...	...
c) *Carburettors or fuel injection*	...	...
d) *Ignition*	...	...
e) *Cooling system*	...	...
f) *Clutch, etc.*	...	...

South African.	New Zealand Government.	Western Australian Government.	Tasmanian.
60 H. P. petrol-mech.	100 H. P. steam. 23	100 H. P. steam. 24	100 H. P. petrol-mech.
...	Clayton standard, coal-fired.	Sentinel standard, coal-fired.	...
Two Hudson car engines.	Clayton.	Sentinel standard horizontal.	Leyland.
6 each.	2	6	6
3 1/2"×5"	6 3/4"×10"	6"×7" sglé. actg.	5 1/2"×6 1/2"
...	230 lb. p. sq. in.	300 lb. p. sq. in.	...
...	...	...	...
4-cycle.	...	...	4-cycle.
29.4 H. P.	62 H. P.	...	...
...	84 H. P. at 450 r. p. m.	100 H. P. at 1 000 r. p. m.	100 H. P.
90 H. P. approx. at 3 600 r. p. m.	...	...	...
Not available.	...	...	...
...	...	Not given.	Not available.
Petrol.	Coal.	Coal.	Petrol.
...	...	...	Not available.
...	...	...	...
...	...	...	...
...	11 000 B. T. U. per lb.	Not given.	...
Splash.	Splash.	Forced.	Pressure.
...	...	Wakefield's Sentinel.	Not available.
(I) Yes. (II) Yes.	...	(I) —. (II) Yes.	(I) No. (II) Yes.
No.	...	No.	None.
Marvel carburettor.	...	...	Carburettor.
Battery.	...	...	Battery and magneto.
Water, radiators and fans.	...	...	Water.
Single disc, cork inserts, in oil.	...	...	Hele Shaw wet plate

Name of railway	**Nigerian.**	**Sudan Government.**
Type of car	100 H. P. steam. 20	100 H. P. steam. 21
3. *Gas producer, particulars and description, and method of working; including scrubbers, gas cleaners, starting blower, etc.*	...	...
4. *Electric accumulator :*		
Acid or alkaline.	...	...
Number, type, size and capacity of cells.		
Weight of battery.		
Normal charging rate.		
Maximum charging rate.		
Maximum discharge, rate, etc.		
5. *Electric generator (petrol or oil-Electric) :*		
Rating	...	...
System of field wiring	...	...
Self or separately excited	...	...
Attachment to engine, etc.	...	...
6. *Gear box :*		
Description and arrangement	Sentinel.	Clayton standard. Crankshaft geared to dvg. axle (totally enclosed)
Drawing if available	...	
Gear ratio	...	1.5 : 1
7. *Final drive—Mechanical transmission :*		
Description and arrangement	...	...
Drawing if available	Sentinel.	Coupling rods to second axle.
Gear ratio	...	...
8. *Motors—Electric transmission :*		
Number and rating	...	...
System of suspension	...	...
Direct, spur gear, bevel gear, or worm drive.	...	...
Gear ratio, etc.	...	...

South African.	New Zealand Government.	Western Australian Government.	Tasmanian.
60 H. P. petrol-mech. [illegible]	100 H. P. steam. 23	100 H. P. steam. [illegible]	100 H. P. petrol-mech. 25
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...
Hudson gear box; unit construction with engine. Three forward and reverse.	Clayton model enclosed.	Sentinel standard.	4-speed clash type.
	...	...	...
...	1.25 : 1	1.25 : 1.	...
Bevel gear to 2 independent layshafts. Inverted tooth, silent chain drives to axle.	Coupling rods to second axle.	Sentinel Standard.	Reversing type crown wheels and pinion on two axles.
	...	...	
7.18 : 1 over all.	...	41 : 34	...
...	...	...	...
...	...	...	...
...	...	...	...
...	...	...	...

Name of railway	**Nigerian.**	**Sudan Government.**
Type of car 1	100 H. P. steam. 20	100 H. P. steam. 21
9. *Control—Mechanical transmission :*		
Single end or double end control	Double.	Double.
Arrangement for reverse running	...	Reversing steam engine.
Full description of the control system	...	Regulator, reversing gear, vacuum brake and ejector can be operated from either cab through push pull rods.
Equipment of control cabin remote from engine.	Duplicate of front end.	
10. *Control—Electric transmission :*		
Full description of system of control adopted, whether engine speed, generator field, motor connection, rheostatic, or a combination of one or more of the above.	...	...
Is provision made for multiple unit control ?	...	No.
11. *Auxiliary equipment :*		
Provision for starting engine	Self starting.	Engine is self starting.
Power for train lighting, heating, etc.	...	Stone's A. Z. axle-driven generator.
Power for continuous brake system	...	Steam ejector.
Electric accumulator (for car types other than battery cars).	...	24 cells 9-plate standard Tonum.
12. *Amount of fuel and water which can be carried on the rail motor :*	Not given.	1 120 lb. coal. 550 gals. water.
Provision made for supply of fuel and water or for recharging accumulators :		
a) *At depot stations*	...	Loco. supplies.
b) *En route.*	...	...
13. *Safety precautions taken in the event of :*		
Fire	...	Chemical fire exting.
Disablement en route	...	...
14. *Information regarding most difficult service worked with rail cars.*	...	...
...	...	...

South African.	New Zealand Government.	Western Australian Government.	Tasmanian.
60 H. P. petrol-mech. 22	100 H. P. steam. 23	100 H. P. steam. 24	100 H. P. petrol-mech. 25
Single. In gear box. Independent controls for each engine on either side of driver.	Double. Reversing engine. Regulator, etc., controls in each end cabin.	Double. Reversing engine. Regulator, etc., controls in each end cabin.	Double. Usual gear lever reversing lever, clutch, pedal accelerator, etc. Duplicate of front end.
...	...	...	...
No.	No.	No.	No.
Electric or hand.	Self starting.	Self starting.	Hand and electric.
Ordinary car generators.	Axle driven generator.	Axle driven generator. (Stone's).	Axle driven generator.
Compressor driven off one lay shaft.	Steam ejector.	Steam ejector.	Compressor driven off engine shaft.
Car battery.	...	...	16 v. miniature Tonum.
65 Imp. gals. petrol. 12 gals. water.	Sufficient for 100 miles.	2 240 lb. coal. 400 gals. water.	50 Imp. gals. petrol. 50 gals. water.
...	Loco. supplies.	Loco. supplies.	Underground tanks and pumps.
...	...	...	Containers.
Fire extinguishers.	...	Chem. extinguishers.	Chem. extinguishers.
Portable telephones.	...	...	...
Can ascend grade of 3.3 % in top gear with full load at 22 m. p. h.	...	...	...
No specifications.	...	...	B. S. S. — or A. C. E. S. A. specification.

Name of railway	**New South Wales Government.**	**New York Central.**
Type of car 1	100 H. P. petrol-mech. 26	500 H. P. gas-electric. 27
1. *Steam boiler, particulars and description*	...	...
2. *Engine*	Leyland.	2 engines.
Number of cylinders	6	6 each.
Bore and stroke	5 1/2"×6 1/2"	7 1/4"×8"
Boiler pressure (for steam)	...	...
Mean effective pressure	...	87 lb. p. sq. in.
Two or four-cycle	4-cycle.	4-cycle.
Rated horse-power	72 H. P.	250 H. P.
Brake H. P. at governed speed — r. p. m.	90 H. P. at 1 000 r. p. m.	250 H. P. at 1 100 r. p. m.
Maximum B. H. P. at — r. p. m.	108 H. P. at 1 200 r. p. m.	...
Fuel consumption — lb. per B. H. P.-hour at :		
a) *Normal output*	0.605 lb.	0.6 lb.
b) *Maximum output*	0.651 lb.	0.65 lb.
Fuel :		
a) *Physical properties*	Water white.	Gasoline.
b) *Specific gravity*	743	...
c) *Viscosity*	...	...
d) *Distillation ranges, etc.*	Initial 113° F. 50 % 246° F. End point 392° F. 97 % recovery.	Initial 131° F. 50 % 280° F. End point 437° F. 95 % recovery.
e) *Calorific value (B. T. U. per lb. for solids and liquids; B. T. U. per cubic foot for gas).*	19 500 B. T. U. per lb.	...
Lubrication system	Pressure.	Pressure.
Lubricating oil, physical properties	Sp. gr.=0.909. Flash open, 485° F., cold 23° F. Visc. 100° F.=1 033 secs. 140° F.=302 secs. 212° F.=77 secs. Red.	Viscosity: 100° F.=1 145 secs; 210° F.=98 secs. « Saybolt ».
Auxiliaries :		
a) *(I) fuel, (II) oil strainers*	(I) Auto Klean. (II) Gauze.	(I) Gasolator. (II) Yes.
b) *Air cleaners*	Air taken from inside car through gauze.	Air maze.
c) *Carburettors or fuel injection*	Claudel-Hobson carburettor.	Carburettors.
d) *Ignition*	Battery and magneto.	Battery or magneto.
e) *Cooling system*	Water, natural ventilated roof radiators.	Water, radiators and fans.
f) *Clutch, etc.*	Multi dry plate.	None.

Name of railway	**New South Wales Government.**	**New York Central.**
Type of car	100 H. P. gas-electric. 26	500 H. P. petrol-mech. 20
3. *Gas producer, particulars and description, and method of working; including scrubbers, gas cleaners, starting blower, etc.*	...	...
4. *Electric accumulator :*		
Acid or alkaline. *Number, type, size and capacity of cells.* *Weight of battery.* *Normal charging rate.* *Maximum charging rate.* *Maximum discharge, rate, etc.*	...	...
5. *Electric generator (petrol or oil-electric):*		
Rating	...	160 kw.
System of field wiring	...	Differential field.
Self or separately excited	...	Separately excited.
Attachment to engine, etc.	...	Direct.
6. *Gear box :*		
Description and arrangement	4-speed clash type. No reverse, otherwise orthodox.	...
Drawing if available		...
Gear ratio	4.42, 2.53, 1.6 and direct.	...
7. *Final drive—Mechanical transmission :*		
Description and arrangement	Reversing type, crown wheels and pinion.	...
Drawing if available	...	...
Gear ratio	2.7 : 1	...
8. *Motors—Electric transmission :*		
Number and rating	...	Four 140 H. P. 450-v.
System of suspension	...	Nose.
Direct, spur gear, bevel gear, or worm drive.	...	Spur.
Gear ratio, etc.	...	61 : 18.
9. *Control—Mechanical transmission :*		
Single end or double end control	Double.	...
Arrangement for reverse running	Reversing final drive.	
Full description of the control system	Gate change gear lever, final drive, reversing lever, clutch pedal, accelerator pedal, etc., in each cabin.	
Equipment of control cabin remote from engine.		...

Name of railway	**New South Wales Government.**	**New York Central.**
Type of car 1	100 H. P. gas-electric. 26	500 H. P. petrol-mech. 27
10. *Control—Electric transmission :*		
Full description of system of control adopted, whether engine speed, generator field, motor connection, rheostatic, or a combination of one or more of the above.	...	Engine speed and differential field generator.
Is provision made for multiple unit control ?	No.	No.
11. *Auxiliary equipment :*		
Provision for starting engine	Hand and electric.	Generator starting.
Power for train lighting, heating, etc.	Battery charged from trn. lgt. generator driven from engine shaft.	Battery charged by 60-v. exciter.
Power for continuous brake system	DH-16 air compressor driven off engine.	Motor driven compressor.
Electric accumulator (for car types other than battery cars).	16-v. lead type, 120 A. H. cap.	16-cell, type M. V. H. 13 225 A. H. cap. at 6-hour rate.
12. *Amount of fuel and water which can be carried on the rail motor :*	70 Imp. gals. petrol. 30 do. water.	420 Imp. gals. gas. 67 gals. water.
Provision made for supply of fuel and water or for recharging accumulators :		
a) *At depot stations*	Underground tanks and pumps.	Tanks and pumps for gas. Hose for water.
b) *En route.*	...	None.
13. *Safety precautions taken in the event of :*		
Fire.	2 Pyrene exting.	CO_2 extinguishers.
Disablement en route	Portable telephone. Manual tricycle.	...
14. *Information regarding most difficult service worked with rail cars.*	Most difficult service is Narrandera Tocumwal, not on account of grades, but because of the fast table (avge. speed 28 m. p. h.) with trailer, and prevalence of strong winds; the engine is working at full output for long periods.	Single unit gas-elec. car (250 H. P.), Corning to Ulysses. Max. grade 1.67 %. Avge. 0.52 %; length 2.5 miles per stop, no trailer. Avge. speed 26.5 m. p. h. — Dual engine unit Toledo to Thurston. Grade 0.75 % avge. Length 6 miles per stop. 2 trailers. Weight 140 tons. Average speed 36.3 m. p. h.
...	B. S. S. and A. C. E. S. A. specifications.	Specifications supplied.

PART IV.

TECHNICAL AND ECONOMIC RESULTS.

Name of railway 1	**Baltimore and Ohio.** 2	**Boston and Maine.** 3
1. *Type of service operated :*		
Main line	Yes.	Yes.
Branch line.	Yes.	Yes.
Suburban (commuter)	Yes.	Yes.
Are these services operated by rail motor alone, or by rail motor and trailer ?	Generally with trailer.	Both.
2. *Speed :*		
Maximum speed possible on level	50 m. p. h.	60 m. p. h.
For each type of service enumerated in (1) above please give :		
a) *Maximum speed in regular service* . .	45 m. p. h.	55 m. p. h.
b) *Schedule speed in regular service.* . .	27 m. p. h.	25 m. p. h.
For rail motor alone and for rail motor and trailer.	With trailer.	Immaterial.
3. *Distance travelled :*		
For each type of service enumerated in (1) please give :		
a) *Average mileage per day run by rail motor..*	175 210 53	Gas-mech. Gas-elec. 100 142
b) *Average mileage run by driver per day of ..... hours.*	175 210 53	100 100
For all types of service, what is the average mileage run per car per annum ?		
a) *for rail motor cars*	47 464	25 000 36 700
b) *for trailers*	32 844	Not available.
4. *Consumption of fuel, etc.:*		
Miles per Imperial gallon of petrol (gasoline) or fuel oil.	Gas-mech. Gas-elec. 2.76 1.8	Gasoline. 2.0
Miles per 100 lb. coal, coke or charcoal. (Please state which.)	...	...
Kilowatt-hours per mile	...	...
Miles per Imperial gallon of water	...	...
Miles per Imperial gallon of lubricating oil.	144 91	72

and economic results.

Central of Georgia. 4	Chesapeake and Ohio. 5	Great Northern. 6	Gulf Coast and Internat. Great Northern. 7
No.	Yes.	Yes.	Yes.
Yes.	...	Yes.	No.
No.	...	No.	No.
Rail motor alone.	Alone with gas-mech. Gas-elec. with trailer.	Both.	Rail motor alone.
42 m. p. h.	30 m. p. h. gas-mech. 60 m. p. h. gas-elec.	65 m. p. h.	Gas-electric 55 m. p. h.
30 m. p h.	25 m. p. h. gas-mech. 60 m. p. h. gas-elec.	50 to 55 m. p. h.	...
28 m. h. p.	18 m. p. h. gas-mech. 30 m. p. h. gas-elec.	25.8 m. p. h	...
Rail motor alone.	...	No great difference.	...
99	87 gas-mech. 205 gas-elec.	170	135
99	87 gas-mech. 123 ges-elec.	170	135
29 445	66 209	62 600	50 000
...	52 100	...	...
Gasoline. 5.3 approx.	Gasoline. 1.8	Gasoline 1.68 (34 cars). Fuel oil 2.04 (1 car).	Gasoline. 2.88
...	...	...	...
...	...	...	...
...	...	...	...
26.4 approx.	180	Not given.	...

Name of railway	**Baltimore and Ohio.** 2	**Boston and Maine.** 3
5. *Unit costs for fuel, etc.:*		
Cost per Imperial gallon of petrol (gasoline) or fuel oil, delivered to the rail motor.	Gasoline. 12.1 cents.	Gasoline. 13.2 cents.
Cost per ton of coal, coke or charcoal, delivered to the rail motor (2 240 lb.-ton).	...	...
Cost per kw.-hour of energy put into accumulator.	...	...
Cost per Imperial gallon of lubricating oil.	...	66 cents.
6. *Unit labour costs :*		
Rate paid to driving staff per man per day of ..... hours.	$ 6.62 100 miles or less.	$ 7.53 100 miles or less.
Rate paid to assistant staff (guards, conductors) per man per day of ..... hours.	Conductor $ 7.20 Baggageman $ 5.22 Brakeman $ 5.05 150 miles or less.	Conductor $ 7.50 Baggageman $ 5.55 Brakeman $ 5.35 150 miles or less.
Rate paid to mechanics per man per day of ..... hours.	$ 6.40 8 hours.	$ 6.40 8 hours.
7. *Unit capital charges*	Average all cars $ 41 555.	Average all cars $ 32 644.
Cost of rail motor	Latest car $ 68 838.	Machinery $ 14 177 Car $ 18 467
If different depreciation allowances are made for engine and car bodies, please give separate cost of each part.	No.	...
Rate of depreciation allowed.	12 %	Machinery 12 1/2 % Car 5 %
8. *Operating costs (average):*		
Cost per rail motor mile for :		Gas-mech. Cents. — Gas-elec. Cents.
a) *Fuel or power*	*a*) 6.76 cents.	*a*) 4.44 — 7.09
b) *Stores (lubricating oil, spark plugs, etc.)*	*b*) 3.87 »	*b*) 1.36 — 1.39
c) *Running repairs, cleaning, etc.*	c) included in (*e*) ;	*c*) 13.24 — 9.61
d) *Operating staff*	*d*) 18.39 cents.	*d*) 26.80 — 22.60
e) *General overhaul*	*e*) 10.19 »	*e*) 5.00 — 5.00
Is the last item charged for as it actually accrues, or is it provided for by an allowance estimated from past experience.	As it accrues.	As it accrues.

* Drivers only.

Central of Georgia. 4	Chesapeake and Ohio. 5	Great Northern. 6	Gulf Coast and Internat. Great Northern. 7
Gasoline. 14.4 cents.	Gasoline. 13.2 cents.	Gasoline 6.6 cents. Fuel oil 4.56 »	Gasoline. 12 cents.
...	...	...	...
...	...	...	...
54 cents.	67.2 cents	52.2 cents.	...
$ 7.28 8 hours.	$ 6.65 100 miles.	$ 6.56 8 hours or 100 miles.	$ 7.00 8 hours.
$ 7.20 8 hours.	Conductor $ 216 Assistant $ 156.60 per month.	...	...
$ 6.40 8 hours.	$ 6.40 8 hours.	Mechanics 81 cents. Helpers 57 » per hour.	$ 6.48 8 hours.
Gas-mech. $ 19 520.	...	Average of 35 cars $ 42 411.	Average $ 22 500.
Machinery $ 7 808 Car $ 11 712	Gas-electric. $ 53 000	Machinery $ 21 846 Car $ 20 565	...
...	No.	...	No.
Machinery 12 1/2 % Car 5 %	4 %	Engine 7 % Car 4 %	3 1/2 %
Gas-mech.	Gasoline-elec.	Gasoline. Cents. — Fuel oil. Cents.	Gas-electric.
a) 3.4 cents.	a) 6.23 cents.	a) 6.65 — 2.09	a) 25 cents
b) 2.7 »	b) 3.90 »	b) 1.28 — 0.76	b)
c) 1.8 »	c) Included in (e)	c) 1.25 — 1.67	c)
d) 17.68 »	d) 16.71 cents.	d) 7.12* — 6.58*	d)
e) No record.	e) 9.18 »	e) 5.33 — 1.41	e) Varies.
...	As it accrues.	As it accrues.	As it accrues.

Name of railway	**Baltimore and Ohio.** 2	**Boston and Maine.** 3
9. *Are the operating costs given in the reply to the preceding question the results of short-time operation, or are they the results after a number of years' experience ?*	...	Five years' experience.
If the latter, please state the period. . . .	Figures for year 1930.	...
Please state the number of cars included in the average.	20	7 16
10. *How is the cost of superintendence provided for ? Is the cost of special staff controlling the rail motors charged wholly against rail motors, or is it included in the general superintendence costs of the railway system ?*	Charged against rail motors.	Included in general superintendence.
If the former, what is the cost of this special superintendence per rail motor mile ?	10.12 cents.	...
11. *What is the total cost per rail motor mile, including operating costs, depreciation and special superintendence ?*	All cars. $ 0.5933	Gas-mech. $ 0.561 Gas-elec. $ 0.613
12. *What is the revenue obtained per rail motor mile ?*	$ 0.3485	Not available.
13. *For purposes of comparison, please give operating costs for the steam train displaced by the rail motor or which would have to be run if the rail motor were not operated?*	Comparison of average out of pocket costs: Steam train 91.6 cents. Rail motor 39.2 »	...
Cost per steam train-mile for :		
a) *Fuel and water*	...	*a*) 21.2 cents.
b) *Stores*	...	*b*) 9.3 »
c) *Running repairs, cleaning, etc.* . . .	...	*c*) 6.0 »
d) *Operating staff*	...	*d*) 36.0 »
e) *General overhaul*	...	*e*) 30.49 »
14. *Is there any special superintendence, the cost of which would be chargeable against such steam train, and not against the rail motor ?*	No.	No.
If so, what would this amount to, per steam train-mile ?		
15. *What would depreciation amount to per steam train-mile ?*	2.06 cents.	Not available.
Please indicate the capital cost of the steam train, and the rate of depreciation.	$ 37 400 3 %	Locomotive 3 % Cars 2 %

Central of Georgia. 4	Chesapeake and Ohio. 5	Great Northern. [illegible]	Gulf Coast and Internat. Great Northern. 7
...	...	...	Experience.
2 years. 1	Figures for year 1930. 6	Figures for year 1930. 34 1	Figures for 12 months. 8
Included in general superintendence.	Included in general superintendence.	Included in general superintendence	Included in general superintendence.
...	...	...	...
Gas-mechanical. $ 0.3174	Gas-electric. $ 0.4124	Gasoline-elec. $ 0.3992 Fuel oil-elec. $ 0.3061	...
$ 0.197	$ 0.3067	$ 0.4645	$ 0.1500
...	...	...	...
a) 6.97 cents. b) 2.91 » c) 14.60 » d) 30.46 » e) No record.	a) 8.11 cents. b) 3.75 » c) 34.86 » d) 23.93 » e) ...	a) 22.59 cents. b) 6.30 » c) 18.77 » d) 31.70 » e) 4.95 »	a) b) c) d) e) } 48.5 cents.
No.	No.	No.	No.
2.81 cents.	2.91 cents.	4.30 cents.	7.5 cents.
$ 18 767 Locomotive 3 3/4 % Cars 3 %	$ 60 000 4 %	$ 39 638 4 %	$ 75 000 3 1/2 %

Name of railway 1	**Missouri-Pacific.** 8		**Missouri-Kansas and Texas.** 9	
1. *Type of service operated :*				
Main line	No.		No.	
Branch line.	Yes.		Yes.	
Suburban (commuter)	No.		No.	
Are these services operated by rail motor alone, or by rail motor and trailer ?	Both.		Rail motor alone.	
2. *Speed :*				
Maximum speed possible on level	50 m. p. h.		Gas-mech. 58 m. p. h.	Gas-elec. 50 m. p. h.
For each type of service enumerated in (1) above please give :				
a) *Maximum speed in regular service*	50 m. p. h.		40 m. p. h.	40 m. p. h.
b) *Schedule speed in regular service.*	32 m. p. h.		26 m. p. h.	26 m. p. h.
For rail motor alone and for rail motor and trailer.	...		No trailers.	
3. *Distance travelled :*				
For each type of service enumerated in (1) please give :-				
a) *Average mileage per day run by rail motor.*	...		108	147
b) *Average mileage run by driver per day of ..... hours.*	206		108	147
For all types of service, what is the average mileage run per car per annum ?				
a) *for rail motor cars*	69 350		Not stated.	
b) *for trailers*	...		...	
4. *Consumption of fuel, etc.:*				
Miles per Imperial gallon of petrol (gasoline) or fuel oil.	Gas-mech. 8.4	Gas-elec. 2.4	Gas-mech. 3.36	Gas-elec. 2.04
Miles per 100 lb. coal, coke or charcoal. (Please state which.)	...		...	
Kilowatt-hours per mile	...		...	
Miles per Imperial gallon of water	...		...	
Miles per Imperial gallon of lubricating oil.	98.4	86.4	40	55 (includes grease).

Minneapolis, St. Paul and Sault - Ste Marie. 10	New York, New Haven and Hartford. 11		Northern Pacific. 12	Reading Company. 13
Yes.	No.		Not specified.	No.
No.	Yes.		...	Yes.
No.	No.		...	No.
Motor and trailer.	Mostly rail motor alone		...	Generally with trailer.
60 m. p. h.	Gas-mech. and hyd.	Gas-elec.	Latest gas-elec. 70 m. p. h. approx.	70 m. p. h. gas-elec.
50 m. p. h.	45 m. p. h.	60 m. p. h.	60 m. p. h. approx.	Up to 55 m. p. h.
28.6 m. p. h.	26 m. p. h.		20 to 30 m. p. h.	25 m. p. h.
With trailer.	Trailers do not affect speed.		Either alone or with trailer.	With trailer.
372.4	87	126	176 (88 to 415)	134
186.2 6.5 hours.	77 8 hours.	101	...	134 8 hours.
85 272 miles.	12 700	32 000	65 000	30 800
85 272 miles.	...		65 000	21 400
Gasoline. 2.48	Gas-mech. and hyd. 3.7	Gas-elec. 1.8	Gasoline. 2.06	Gasoline. 1.27 Fuel oil. 2.88
...	...		...	...
...	...		...	...
...	...		...	...
240	65	98	50.07	51.6

Name of railway 1	**Missouri-Pacific.** 8	**Missouri-Kansas and Texas.** 9
5. *Unit costs for fuel, etc.:*		
Cost per Imperial gallon of petrol (gasoline) or fuel oil, delivered to the rail motor.	Gasoline. 9.6 cents.	Gasoline. 8.4 cents.
Cost per ton of coal, coke or charcoal, delivered to the rail motor (2 240 lb.-ton).	...	...
Cost per kw.-hour of energy put into accumulator.	...	...
Cost per Imperial gallon of lubricating oil. .	45.6 cents.	51.5 cents.
6. *Unit labour costs :*		
Rate paid to driving staff per man per day of ..... hours.	$ 7.46 100 miles or less.	$ 7.50 8 hours.
Rate paid to assistant staff (guards, conductors) per man per day of ..... hours.	Conductor $ 7.44 Baggageman $ 5.20 150 miles or less.	$ 7.50 8 hours.
Rate paid to mechanics per man per day of ..... hours.	81 cents per hour.	$ 195 per month.
7. *Unit capital charges*	...	$ 23 084 gas-mech. $ 34 015 gas-elec.
Cost of rail motor	...	Machinery : $ 9 200 gas-mech. $ 15 350 gas-elec. Car : $ 13 884 gas-mech. $ 18 665 gas-elec.
If different depreciation allowances are made for engine and car bodies, please give separate cost of each part.	...	...
Rate of depreciation allowed.	...	Machinery 20 % Car 3 %
8. *Operating costs (average):*		
Cost per rail motor mile for :		Gas-mech. Gas-elec. Cents. Cents.
a) *Fuel or power*	*a)* ...	*a)* 3.77 6.88
b) *Stores (lubricating oil, spark plugs, etc.)*	*b)* ...	*b)* 2.30 1.19
c) *Running repairs, cleaning, etc.* . . .	*c)* ...	*c)* Included in (*e*) ;
d) *Operating staff*	*d)* 23 to 17 cents for driver and conductor; 3.5 to 6 cents for baggagemen where used.	*d)* 17.30 15.48
e) *General overhaul*		*e)* 18.08 7.46
Is the last item charged for as it actually accrues, or is it provided for by an allowance estimated from past experience.	...	As it accrues.

Minneapolis, St. Paul and Sault - Ste Marie. 10	New York, New Haven and Hartford. 11	Northern Pacific. 12	Reading Company. 13
Gasoline. 14.3 cents.	Gasoline. 10.8 cents.	Gasoline. 12.9 cents.	Gasoline. 13.6 cents. Fuel oil. 5.36 cents.
...	...	...	...
...	...	...	...
61 cents.	80 cents.	47.6 cents.	55.6 cents.
$ 6.75 100 miles.	$ 7.53 8 hours.	$ 7.46 8 hours.	$ 7.53 8 hours.
$ 4.88 100 miles.	$ 7.20 8 hours.	Conductor $ 7.375 Brakeman $ 5.035 7 1/2 hours.	Conductor $ 7.50 Baggageman $ 5.52 Brakeman $ 5.31 8 hours.
81 cents per hour.	$ 6.32 8 hours.	81 cents per hour.	$ 6.48 8 hours.
Gas-electric. $ 33 500	$ 20 000 gas-mech. $ 45 289 gas-elec.	Average. $ 45 000	Average of all cars $ 53 894
...	Machinery $ 21 507 Cars $ 23 782 for gas-elec.	...	Latest cars average $ 63 262
No.	No subdivision for gas-mechanical.	...	No.
4.5 %	Machinery and all gas-mech. } 10 % Car (gas-elec.) 5 %	8 % for statistics. (4 % for accounting).	4 1/2 %
a) 5.73 cents. *b*) 1.26 » *c*) 5.24 » *d*) 18.81 » *e*) 2. 0 »	*a*) *b*) *c*) } 48 cents. *d*) *e*)	*a*) 6.25 cents. *b*) 1.46 » *c*) 5.64 » *d*) 13.52 » *e*) 2.38 »	*a*) 9.09 cents. *b*) 1.59 » *c*) Included in (*e*). *d*) 22.6 cents. *e*) 14.11 » Including trailer costs.
As it accrues.	At is accrues.	As it accrues.	As it accrues.

Name of railway 1	**Missouri-Pacific.** 8	**Missouri-Kansas and Texas.** [illegible]
9. *Are the operating costs given in the reply to the preceding question the results of short-time operation, or are they the results after a number of years' experience ?*	…	Number of years.
If the latter, please state the period. . . .	…	4 years.
Please state the number of cars included in the average.	…	1 1
10. *How is the cost of superintendence provided for ? Is the cost of special staff controlling the rail motors charged wholly against rail motors, or is it included in the general superintendence costs of the railway system ?*	…	Included in general superintendence.
If the former, what is the cost of this special superintendence per rail motor mile ?	…	…
11. *What is the total cost per rail motor mile, including operating costs, depreciation and special superintendence ?*	Gas-mech. $ 0.3200 Gas-elec. $ 0.3500	Gas-mech. $ 0.4833 Gas-elec. $ 0.3716
12. *What is the revenue obtained per rail motor mile ?*	Not available.	Not available.
13. *For purposes of comparison, please give operating costs for the steam train displaced by the rail motor or which would have to be run if the rail motor were not operated?*	…	…
Cost per steam train mile for :		
a) *Fuel and water*	*a*) Not given.	*a*) 4.90 cents.
b) *Stores*	*b*)	*b*) 6.22 »
c) *Running repairs, cleaning, etc.* . . .	*c*)	*c*) Included in (*e*) ;
d) *Operating staff*	*d*)	*d*) 54.08 cents.
e) *General overhaul*	*e*)	*e*) 14.92 » Water included in (*e*).
14. *Is there any special superintendence, the cost of which would be chargeable against such steam train, and not against the rail motor ?*	Not given.	No.
If so, what would this amount to, per steam train mile ?		
15. *What would depreciation amount to, per steam train mile ?*	…	4.5 cents.
Please indicate the capital cost of the steam train, and the rate of depreciation.	Not given.	$ 44 003 Locomotive 3 % Cars 4 %

Minneapolis, St. Paul and Sault - Ste Marie. 10	New York, New Haven and Hartford. 11	Northern Pacific. 12	Reading Company. 13
Short time.	...	...	Number of years.
... 1	Figures for year 1930. 36	Figures for one year. 22	Figures for year 1930. 16
No special staff.	Included in general superintendence.	Included in general superintendence.	Included in general superintendence.
...	...	...	...
Gas-electric. $ 0.3734	All cars. $ 0.6100	Gas-electric. $ 0.4009	All cars. $ 0.5665
...	Not available.	$ 0.3605	Not given.
...	...	...	...
a) 14.12 cents. *b*) 0.96 » *c*) 5.51 » *d*) 23.81 » *e*) 6.62 »	*a*) *b*) *c*) *d*) *e*) } $ 1.25	*a*) *b*) *c*) *d*) *e*) } Not stated.	*a*) *b*) *c*) } 75.4 cents. *d*) *e*) } 44.82 cents.
No.	No.	Not stated.	No.
...	Indeterminate.	Not stated.	8.94 cents.
$ 24 340 3 %	...	...	$ 64 582 4 1/2 %

Name of railway 1	**Southern Pacific.** 14	**Canadian National.** 15
1. *Type of service operated :*		
Main line	Not specified.	Yes.
Branch line.	...	Yes.
Suburban (commuter)	...	No.
Are these services operated by rail motor alone, or by rail motor and trailer ?	Both.	Both.
2. *Speed :*		
Maximum speed possible on level	Gas-electric. Not stated.	40-60 m. p. h. without trailer.
For each type of service enumerated in (1) above please give :		
a) *Maximum speed in regular service*	Not stated.	60 m. p. h. 40 m. p. h.
b) *Schedule speed in regular service.*	Not stated.	30 m. p. h. 25 m. p. h.
For rail motor alone and for rail motor and trailer.	...	Without trailer.
3. *Distance travelled :*		
For each type of service enumerated in (1) please give :		
a) *Average mileage per day run by rail motor.*	225	152
b) *Average mileage run by driver per day of ..... hours.*	Not stated.	100 miles. 8 hours.
For all types of service, what is the average mileage run per car per annum ?		
a) *for rail motor cars*	...	36 000
b) *for trailers*	...	Variable.
4. *Consumption of fuel, etc.:*		
Miles per Imperial gallon of petrol (gasoline) or fuel oil.	Gasoline and distillate. 1.16 approx.	Gas-mech. 6.58 Gas-elec. 2.08 Fuel oil 3.55 (6 cyl.).
Miles per 100 lb. coal, coke or charcoal. (Please state which.)	...	...
Kilowatt-hours per mile	...	4.06
Miles per Imperial gallon of water	...	...
Miles per Imperial gallon of lubricating oil.	...	Gas-mech. 112 Gas-elec. 82 Diesel-elec. (6 cyl.) 33

Chosen Government. 16	Japanese Government. 17	Federated Malay States. 18	East Indian. 19
No.	Yes.	No.	Yes.
Yes.	Yes.	Yes.	Yes.
Yes.	No.	No.	No.
Rail motor alone.	Rail motor alone.	Articulated unit.	Rail motor alone.
34-44 m. p. h.	31-40 m. p. h.	40 m. p. h.	35 m. p. h.
35-44 m. p. h. 44 m. p. h.	31 m p. h.	35 m. p. h.	30 m. p. h.
22-27.5 m. p. h. 27.5 m. p. h.	19 m. p. h.	19 m. p. h.	21 m. p. h.
Rail motor alone.	Rail motor alone.	Articulated unit.	Rail motor alone.
117	60	[illegible]	100
46			
77	34	80	100
56	10	8 hrs. 7 mins.	10
7 hours approx.			
25 000 approx.	20 000	28 000	27 000
...	...	...	...
Petrol.	Petrol.	...	...
10 approx.	6.28		
Coal.	Coal.	Coal.	Coal.
11.2 miles.	8.2	3.68	7
...	...	...	...
...	...	0.179	0.8
178	210	457	20

Name of railway 1	**Southern Pacific.** 14	**Canadian National.** 15
5. *Unit costs for fuel, etc.:*		
Cost per Imperial gallon of petrol (gasoline) or fuel oil, delivered to the rail motor.	Gasoline. 16.6 cents. Distillate. 4.85 cents.	Gasoline. 20.5 cents. Fuel oil. 5.8 cents.
Coal per ton of coal, coke or charcoal, delivered to the rail motor (2 240-lb. ton).	...	...
Cost per kw.-hour of energy put into accumulator.	...	2 cents.
Cost per Imperial gallon of lubricating oil. .	...	Gas-mech. 65 cents. Gas and Diesel-elec.: 80 cents.
6. *Unit labour costs :*		
Rate paid to driving staff per man per day of ..... hours.	Not stated.	$ 6.16 per 100 miles. (min. $ 7.0 per day).
Rate paid to assistant staff (guards, conductors) per man per day of ..... hours.	...	Conductor $ 6.70 Baggageman $ 5.20 per 150 miles.
Rate paid to mechanics per man per day of ..... hours.	...	$ 180 per month.
7. *Unit capital charges*	Gas-elec. $ 79 200	Gas-elec. $ 50 000
Cost of rail motor	Aver. cost of motor train. No. of trailers not known.	Diesel-elec. $ 85 000 (6 cyl.).
If different depreciation allowances are made for engine and car bodies, please give separate cost of each part.	...	...
Rate of depreciation allowed.	...	Gas-elec. Diesel-elec. Eng. 6.7 %. Eng. 6 %. Elec. 4 %. Other equip. Car 4 1/2 %. 4 %
8. *Operating costs (average):*		Gas-elec. Cents. Diesel-elec. (6 cyl.) Cents.
Cost per rail motor mile for :	Gas-electric.	
a) *Fuel or power*	*a*) 6.72 cents.	*a*) 7.0 2.0
b) *Stores (lubricating oil, spark plugs, etc.)*	*b*) 4.66 »	*b*) 2.57 4.59
c) *Running repairs, cleaning, etc.* . . .	*c*) Included in (*e*).	*c*) Included in (*e*).
d) *Operating staff*	*d*) 18.04 cents.	*d*) 24.0 16.0
e) *General overhaul*	*e*) 11.56 »	*e*) 8.43 24.5
Is the last item charged for as it actually accrues, or is it provided for by an allowance estimated from past experience.	As it accrues.	As it accrues.

Chosen Government. 16	Japanese Government. 17	Federated Malay States. 18	East Indian. 19
(1 yen=24 d.) Petrol. 0.5 yen (13.2 d).	(1 yen=24 d.) Petrol. 0.69 yen (16.5 d.)	($ 1=2/4)	Rs. 1=18 d.)
11.9 yen (24 sh.).	10.63 yen (21 sh. 3 d.)	$ 6.25 (14 sh. 7 d.)	Rs. 11 (16 sh. 6 d.)
...	...	...	...
Cyl. 1.30 yens (31.2 d.) Crankcase. 2.70 yens (64.8 d.)	0.78 yen (18.7 d.)	$ 1.50 (3 sh. 6 d.)	12 annas (13.5 d.)
4.04 yen (8 sh.). 10 hours.	1.287 yen (30.8 d.)	Driver: $ 3.45 (8 sh. 3/4 d.) Fireman: $ 1.12 (2 sh. 7 1/4 d.) 8 hours.	Driver Rs. 120 (£ 9) Fireman Rs. 30 (£ 2-5-0) per month.
2.95 yen (5 sh. 11 d.). 10 hours.	0.898 yen (21.5 d.)	Guard: $ 2.45 (5 sh. 8 3/4 d.) 8 hours.	Guard Rs. 130 (£ 9-15-0) per month.
...	0.949 yen (22.8 d.)	Fitter: $ 1.76 (4 sh. 1 1/4 d.) 8 hours.	Mechanics Rs. 40 (£ 3) per month.
Latest steam. 71 200 yen (£ 7 120). Latest petrol. 31 000 yen (£ 3 100).	Petrol-mech. 25 000 yen. (£ 2 500).	$ 70 000 (£ 8 170)	Rs. 131 225 (£ 9 850)
No.	Depreciation not allowed.	No.	No.
...	...	5.72 %	8 1/2 %
Latest steam. / Latest petrol. a) 0.077 yen (1.85 d.) / 0.14 yen. (3.36 d.) b) c) d) e) } Not given.	a) b) c) d) e) } Not stated.	a) 12.0 cents (3.36 d.) b) 0.73 » (0.2 d.) c) 2.76 » (0.77 d.) d) 10.00 » (2.8 d.) e) None to date.	a) b) } 1.4 annas (1.57 d.) c) 1 anna (1.12 d.) d) 3.3 annas (3.71 d.) e) Total Rs. 1 724. (£ 129)
...	...	Will be charged as it accrues.	...

Name of railway 1	**Southern Pacific.** 14	**Canadian National.** 15
9. *Are the operating costs given in the reply to the preceding question the results of short-time operation, or are they the results after a number of years' experience ?*	...	Experience.
If the latter, please state the period. . . .	Figures for two months.	3 to 5 years.
Please state the number of cars included in the average.	11	Gas-elec. 3 Diesel-elec. 5
10. *How is the cost of superintendence provided for ? Is the cost of special staff controlling the rail motors charged wholly against rail motors, or is it included in the general superintendence costs of the railway system ?*	In general superintendence.	Charged against rail motors.
If the former, what is the cost of this special superintendence per rail motor mile ?	...	Gas-elec. 3.63 cents. Diesel-elec. (6 cyl.) 1.4 cents.
11. *What is the total cost per rail motor mile, including operating costs, depreciation and special superintendence ?*	Gas-electric. $ 0.4671	Gas-mech. $ 0.38 Gas-elec. $ 0.47 Diesel elec. 4 cyl. $ 0.50 Diesel elec. 6 cyl. $ 0.45 Diesel elec. 8 cyl. $ 0.79 Stge. battery $ 0.50
12. *What is the revenue obtained per rail motor mile ?*	$ 0.5054	Not stated.
13. *For purposes of comparison, please give operating costs for the steam train displaced by the rail motor or which would have to be run if the rail motor were not operated?*		
Cost per steam train-mile for :		
a) *Fuel and water*	*a)* Not stated.	*a)* Not stated.
b) *Stores*	*b)*	*b)*
c) *Running repairs, cleaning, etc.* . . .	*c)*	*c)*
d) *Operating staff*	*d)*	*d)*
e) *General overhaul*	*e)*	*e)*
14. *Is there any special superintendence, the cost of which would be chargeable against such steam train, and not against the rail motor ?*	Not stated.	Not stated.
If so, what would this amount to, per steam train-mile ?	...	...
15. *What would depreciation amount to, per steam train-mile ?*	Not stated.	Not stated.
Please indicate the capital cost of the steam train, and the rate of depreciation.	...	...

Chosen Government. 16	Japanese Government. 17	Federated Malay States. 18	East Indian. 19
Not stated.	Not stated.	Short time.	...
...	...	9 months.	6 months.
...	...	1	3
Not stated.	Included in general superintendence.	No special staff.	No special staff.
...	...	...	...
Not stated.	Not stated.	$ 0.5750 (16.1 d.) including allowance of $ 0.32 for general overhaul (estimated).	10.8 annas (12.15 d.)
Not stated.	Not stated.	Not available.	18 annas (20.2 d.)
a) b) c) Not stated. d) e)	a) b) c) Not stated. d) e)	a) 31.22 cents (8.75 d.) b) 1.28 » (0.36 d.) c) 3.85 » (1.08 d.) d) 11.0 » (3.08 d.) e) 37.41 » (10.48 d.)	a) b) 6.8 annas (7.65 d.) c) ... d) 1.8 annas (2.02 d.) e) ...
Not stated.	Not stated.	...	No.
...	...	...	...
Not stated.	Not stated.	14.5 cents. (4.06 d.)	3.4 annas (3.82 d.)
...	...	$ 109 000 (£ 12 717) 3.72 %	Rs. 81 566 (£ 6 117) 8 1/2 %

Name of railway 1	**Nigerian.** 20	**Sudan Government.** 21
1. *Type of service operated :*		
Main line	Yes.	Yes.
Branch line.	Yes.	No.
Suburban (commuter)	No.	No.
Are these services operated by rail motor alone, or by rail motor and trailer ?	Rail motor alone.	Rail motor alone.
2. *Speed :*		
Maximum speed possible on level	...	47 m. p. h.
For each type of service enumerated in (1) above please give :		
a) *Maximum speed in regular service* . .	25 m. p. h.	47 m. p. h.
b) *Schedule speed in regular service.* . .	25 m. p. h.	35 m. p. h.
For rail motor alone and for rail motor and trailer.	Rail motor alone.	Rail motor alone.
3. *Distance travelled :*		
For each type of service enumerated in (1) please give :	...	...
a) *Average mileage per day run by rail motor.*	87	70
b) *Average mileage run by driver per day of ..... hours.*	50	70 13
For all types of service, what is the average mileage run per car per annum :		
a) *for rail motor cars*	27 976	22 254
b) *for trailers*	...	...
4. *Consumption of fuel, etc.:*		
Miles per Imperial gallon of petrol (gasoline) or fuel oil.	...	...
Miles per 100 lb. coal, coke or charcoal. (Please state which.)	Coal. 4.6	Coal. 7.83
Kilowatt-hours per mile	...	...
Miles per Imperial gallon of water	...	...
Miles per Imperial gallon of lubricating oil.	178	...

South African. 22	New Zealand Government. 23	Western Australian Government. 24	Tasmanian. 25
No.	No.	No.	Yes.
Yes.	Yes.	Yes.	Yes.
No.	No.	Yes.	No.
Rail motor alone.	Rail motor alone.	Both.	Both.
50 m. p. h.	50 m. p. h.	Petrol-mech. 35 m. p. h. Steam 40 m. p. h.	40 m. p. h.
36 m. p. h.	50 m. p. h.	30 m. p. h. 35 m. p. h.	40 m. p. h. 30 m. p. h.
24.5 m. p. h.	45 m. p. h.	20 m. p. h. 30 m. p. h.	18 m. p. h.
Rail motor alone.	Rail motor alone.	No difference.	No difference
...	...	Petrol-mech.	...
136	143	55	46
136 Avge. day 10 3/4 hrs.	85 8 hours.	55	46
35 000 miles.	Avge. 35 000 miles.	10 000 miles.	13 287
...	...	Not recorded.	Not availale.
Petrol. 6.5	...	Petrol. 6.73	Petrol 7.5 approx
...	Coal. 9.00	Coal. Not yet available.	...
...	3.10	...	...
...	...	...	...
300	Not available.	...	...

Name of railway 1	**Nigerian.** 20	**Sudan Government.** 21
5. *Unit costs for fuel, etc.:*		
Cost per Imperial gallon of petrol (gasoline) or fuel oil, delivered to the rail motor.	...	...
Cost per ton of coal, coke or charcoal, delivered to the rail motor (2 240-lb. ton).	Coal. 18 sh.	Welsh coal. 24 sh.
Cost per kw.-hour of energy put into accumulators.	...	...
Cost per Imperial gallon of lubricating oil. .	3 sh. 10 d.	Sat. cyl. oil 27.3 d. Superheat. oil 48.8 d. Axle oil 39.7 d.
6. *Unit labour costs :*		
Rate paid to driving staff per man per day of ..... hours.	3 sh. 3 d. 8 hours.	£ 4-0-0 per month.
Rate paid to assistant staff (guards, conductors) per man per day of ..... hours.	...	...
Rate paid to mechanics per man per day of ..... hours.	...	£ 6-12-0 per month.
7. *Unit capital charges :*		
Cost of rail motor	£ 4 710 single. £ 7 553 double.	£ 3 870
If different depreciation allowances are made for engine and car bodies, please give separate cost of each part.	...	No. ...
Rate of depreciation allowed.	...	4 %
8. *Operating costs (average):*		
Cost per rail motor mile for :		
a) *Fuel or power*	a) Not stated.	a) 9.0 d.
b) *Stores (lubricating oil, spark plugs, etc.)*	b)	b)
c) *Running repairs, cleaning, etc.*	c)	c)
d) *Operating staff*	d)	d)
e) *General overhaul*	e)	e)
Is the last item charged for as it actually accrues, or is it provided for by an allowance estimated from past experience.	...	...
9. *Are the operating costs given in the reply to the preceding question the results of short-time operation, or are they the results after a number of years' experience ?*	Not stated.	Short time.
If the latter, please state the period. . . .	...	...
Please state the number of cars included in the average.	...	2

South African. 22	New Zealand Government. 23	Western Australian Government. 24	Tasmanian. 25
Petrol. 8.5 d.	...	Petrol. 20.5 d.	Petrol 24 d.
...	Coal. 44 sh. 2 d.	Not stated.	...
...	2.47 d.	...	...
3 sh. 1 d.	...	3 sh. 4 d.	4 sh. 3 d.
11 to 20 sh. 8 hours.	20 sh. 8 hours.	21 sh. 3 d. 8 hours.	16 sh. 10 d. 8 hours.
8 to 15 sh. 9 hours.	18 sh. 8 hours.	...	13 sh. 4 d. 8 hours.
18 to 20 sh. 8 hours.	18 sh. 8 hours.	...	15 sh. 7 d. 7-1/3 hours.
£ 3 500	Steam £ 6 003 Battery £ 15 096	Petrol-mech. £ 3 817 Steam £ 6 136	Latest cars £ 7 250
No.	No for steam car. Battery £ 6 632 Car £ 8 464	Petrol-mech. Body £ 725 Chassis £ 3 092	Not given.
10 % on 60 % of capital value.	Steam car 7 1/2 % Battery 20 % Car 10 %	Body 3 1/2 % Chassis 10 %	Machinery 15 % Body 5 %
	Steam car : Battery car :		
a) 1.71 d.	a) 2.63 d. 7.67 d.	a) Not recorded separately. Total 18.99 d.	a) 3.94 d.
b) 0.21 d.	b) 0.29 d. 0.09 d.	b)	b) 0.19 d.
c) 2.90 d.	c) 0.61 d. 2.08 d.	c)	c) Included in (e).
d) 3.65 d.	d) 8.03 d. 3.24 d.	d)	d) 4.23 d.
e) ...	e) 5.20 d. 3.17 d.	e)	e) 4.77 d.
As it accrues.	As it accrues.	...	As it accrues.
...	After 5 years.	Experience.	One year.
3 to 12 months.	Year 1930-31.	1922-1930	Year 1930-1931
5	1 1	2	10

Name of railway 1	**Nigerian.** 20	**Sudan Government.** 21
10. *How is the cost of superintendence provided for? Is the cost of special staff controlling the rail motors charged wholly against rail motors, or is it included in the general superintendence costs of the railway system?*	Not stated.	Included in general superintendence.
If the former, what is the cost of this special superintendence per rail motor mile?	...	...
11. *What is the total cost per rail motor mile, including operating costs, depreciation and special superintendence?*	Not stated.	...
12. *What is the revenue obtained per rail motor mile?*	...	...
13. *For purposes of comparison, please give operating costs for the steam train displaced by the rail motor or which would have to be run if the rail motor were not operated?*		
Cost per steam train-mile for:		
a) *Fuel and water*	Not stated.	No useful comparison possible.
b) *Stores*		
c) *Running repairs, cleaning, etc.* . . .		
d) *Operating staff*		
e) *General overhaul*		
14. *Is there any special superintendence, the cost of which would be chargeable against such steam train, and not against the rail motor?*	Not stated.	...
If so, what would this amount to, per steam train-mile?	...	...
15. *What would depreciation amount to, per steam train-mile?*	Not stated.	..
Please indicate the capital cost of the steam train, and the rate of depreciation.	...	...

South African. 22	**New Zealand Government.** 23	**Western Australian Government.** 24	**Tasmanian.** 25
Included in general superintendence.	Included in general superintendence.	Not charged.	Charged against rail motors.
...	...	...	Included in above figures.
11.33 d.	Steam car: 22.30 d. Battery car: 26.78 d.	29.87 d. (average for 2 years).	21.41 d.
14.88 d.	Unavailable.	12.64 d. (1922-1930)	Not stated.
Not available.	*a*) 10.06 d. *b*) 0.52 d. *c*) included in (*e*). *d*) 12.75 d. *e*) 11.91 d.	Not stated.	Average locomotive costs as under: *a*) 12.04 d. *b*) 0.78 d. *c*) 2.03 d. *d*) 10.53 d. *e*) 8.23 d.
No.	No.	Not stated.	Not stated.
...	...	...	
Not available.	Train replaced by Steam car: 2.58 d. Batt. car. 1.78 d.	Not stated.	Not stated
...	£ 6 632 Locomotive 3-1/3 % Cars 2.86 %	...	...

Name of railway 1	**New South Wales Government.** 26	**New York Central.** 27
1. *Type of service operated :*		
Main line	Yes.	No.
Branch line.	Yes.	Yes.
Suburban (commuter)	Yes.	No.
Are these services operated by rail motor alone, or by rail motor and trailer ?	Both.	Both.
2. *Speed :*		
Maximum speed possible on level	50 m. p. h.	52.5 m. p. h. witht. trailer. 42-50 m. p. h. with trailer.
For each type of service enumerated in (1) above please give :		
a) *Maximum speed in regular service*	40 m. p. h. 35 m. p. h. 30 m. p. h.	50-60 m. p. h.
b) *Schedule speed in regular service.*	25.8 m. p. h. 23.5 m. p. h. 18.5 m. p. h.	30-40 m. p. h. witht. trailer. 26-36 m. p. h. with trailer.
For rail motor alone and for rail motor and trailer.	For both.	...
3. *Distance travelled :*		
For each type of service enumerated in (1) please give :		
a) *Average mileage per day run by rail motor.*	130 110 134	139
b) *Average mileage run by driver per day of ..... hours.*	130 110 69 day of 7-1/3 hours.	139 8 hours.
For all types of service, what is the average mileage run per car per annum :		
a) *for rail motor cars*	31 000	36 500
b) *for trailers*	17 000	...
4. *Consumption of fuel, etc.:*		
Miles per Imperial gallon of petrol (gasoline) or fuel oil.	Petrol 5.35	Gas-mech. 3.2 Gas-elec. (single) 2.0 » (dual) 1.1
Miles per 100 lb. coal, coke or charcoal. (Please state which.)	...	...
Kilowatt-hours per mile	...	...
Miles per Imperial gallon of water	...	...
Miles per Imperial gallon of lubricating oil.	300	120

Name of railway 1	**New South Wales Government.** 26	**New York Central.** 27		
5. *Unit costs for fuel, etc.:*				
Cost per Imperial gallon of petrol (gasoline) or fuel oil, delivered to the rail motor.	Petrol 22.5 d.	Gasoline 10.9 cents.		
Cost per ton of coal, coke or charcoal, delivered to the rail motor (2 240-lb. ton).	...	...		
Cost per kw.-hour of energy put into accumulators.	...	...		
Cost per Imperial gallon of lubricating oil. .	2 sh. 10 d.	90 cents.		
6. *Unit labour costs :*				
Rate paid to driving staff per man per day of ..... hours.	From 17 sh. 9 d. to 20 sh. 9 d. According to seniority, 7-1/3 hour day.	$ 6.62 to $ 7.53 8 hours.		
Rate paid to assistant staff (guards, conductors) per man per day of ..... hours.	16 sh. 1 d. 7-1/3 hour day.	$ 7.20 8 hours.		
Rate paid to mechanics per man per day of ..... hours.	Running sheds 19 sh. 8 d. 7-1/3 hour day. Workshops: 19 sh. 2 d. 8 hrs. 48 mins. day. (In all cases 44-hr. week)	$ 6.48 8 hours.		
7. *Unit capital charges :*				
Cost of rail motor	£ 5 190	Gas-mech. $ 27 500 Gas-elec. (single) $ 48 000 » (dual) $ 69 000		
If different depreciation allowances are made for engine and car bodies, please give separate cost of each part.	Machinery £ 2 330 Body £ 2 860	...		
Rate of depreciation allowed.	Machinery 10 % Body 3 1/2 %	Gas-mech. 14 % Gas-elec. 10 %		
8. *Operating costs (average):*		Gas-mech.	Gas-elec.	
Cost per rail motor mile for :	Average for 1 year.	Cents	Sgle. Cents	Dual Cents
a) *Fuel or power*	a) 4.2 d.	a) 3.5	5.3	10.1
b) *Stores (lubricating oil, spark plugs, etc.)*	b) 2.0 d.	b) c) 11.3	7.1	9.5
c) *Running repairs, cleaning, etc.* . . .	c) 1.95 d.			
d) *Operating staff*	d) 5.25 d.	d) ...	...	...
e) *General overhaul*	e) 2.0 d.	e) 14.4	10.3	13.8
Is the last item charged for as it actually accrues, or is it provided for by an allowance estimated from past experience.	Allowance based on experience.	As it accrues.		

Name of railway 1	**New South Wales Government.** 26	**New York Central.** 27
9. *Are the operating costs given in the reply to the preceding question the results of short-time operation, or are they the results after a number of years' experience?*	Number of years.	Number of years.
If the latter, please state the period. . . .	8 years.	2 yrs. to 6 yrs.
Please state the number of cars included in the average.	37	Gas-mech. 7 Gas-elec. (single) 8 » (dual) 5
10. *How is the cost of superintendence provided for? Is the cost of special staff controlling the rail motors charged wholly against rail motors, or is it included in the general superintendence costs of the railway system?*	Special superintendence is charged against rail motors.	Charged against rail motors.
If the former, what is the cost of this special superintendence per rail motor mile?	0.3 d.	Gas-mech. 1.5 cts. Gas-elec. Sgle. 1.0 ct. Gas-elec. Dual. 0.5 ct.
11. *What is the total cost per rail motor mile, including operating costs, depreciation and special superintendence?*	18.5 d.	$ 0.675 $ 0.610 $ 0.70
12. *What is the revenue obtained per rail motor mile?*	17.0 d.	$ 0.25 approx. (passengers only).
13. *For purposes of comparison, please give operating costs for the steam train displaced by the rail motor or which would have to be run if the rail motor were not operated.*		
Cost per steam train-mile for:		
a) *Fuel and water*	*a*) 8.90 d.	*a*) 25.9 cents.
b) *Stores*	*b*) Included in (*e*).	*b*) 2.8 »
c) *Running repairs, cleaning, etc.* . . .	c) Included in (*e*).	*c*) 7.16 »
d) *Operating staff*	*d*) 8.50 d.	*d*) 5.93 »
e) *General overhaul*	*e*) 22.15 d.	*e*) 19.5 »
14. *Is there any special superintendence, the cost of which would be chargeable against such steam train, and not against the rail motor?*	No.	No.
If so, what would this amount to, per steam train-mile?	...	...
15. *What would depreciation amount to, per steam train-mile?*	3.32 d.	7.83 cents.
Please indicate the capital cost of the steam train, and the rate of depreciation.	£ 6 584 3 % for locom. 2 1/2 % for cars.	Locomotive $ 21 500 2 cars $ 37 000 2 1/2 %

PART V.

GENERAL OBSERVATIONS.

Name of railway 1	**Baltimore and Ohio.** 2	**Boston and Maine.** 3
1. *What observations have you to make on the results obtained in current service from the point of view of power, and, above all, of flexibility in use, with regard to service requirements ?*	Satisfactory for the runs to which they are assigned.	Generally satisfactory. Hampered at times by lack of flexibility as regards power, seating and baggage capacity and double end operation.
2. *Have you frequently been obliged to replace rail motor cars (R.M.) by locomotives on occasion of large rush of passengers, either of periodic nature, or during certain seasons, or accidently ?*	No.	On certain runs, always on special occasions.
3. *Have you found it advantageous to reduce the classes to one only, even for the trailers ?*	One class only.	One class only.
4. *Has the number of runs of rail motor cars (R.M) interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for principal trains on lines carrying heavy fast passenger and freight train traffic ?*	No.	No such conditions.
5. *Have you experienced difficulties in motor upkeep, in view of special construction generally less robust than that of locomotives ?*	No.	Until men were properly qualified.
If it is necessary to stable and overhaul rail motor cars (R.M.) in steam locomotive sheds, and in view of the connection of interior of car with mechanical portion, have you experienced trouble due to the deterioration of cars, and the difficulty of keeping them in a good state of cleanliness?	No.	Yes, until space was partitioned off.
Have you had trouble due to space so taken up in the sheds ?	No.	No.
6. *Have you in construction other rail motor cars ?*	No.	No.
If so, of what type ?	Larger cars, gas- or oil-elec.	...
Are you thinking of extending their use ?	Under consideration.	No.
7. *What reasons led to adoption of rail motor car operation, and of particular types of car ?*	To economise on operation costs.	Economy. No choice of types when service started.
8. *As the result of experience, have you altered your views on the question ?*	No.	No.
9. *Are you proposing to alter your organisation, or system of operation ?* *If so, in what respect ?*	No.	No.
10. *What is the likely trend of development with regard to rail motors on your railway ?*	Increasing use of units of greater power.	Larger power units.

eneral observations

Central of Georgia. 4	Chesapeake and Ohio. 5	Great Northern. 6	Gulf Coast and internat. Great Northern. 7
Car satisfactory for present run, not suited for any other.	Results satisfactory. Runs were studied in advance and cars built to suit.	First cars of 175 H. P. had limited application. Greater power required and recent purchases are 400 H. P.	None.
Very seldom.	Infrequent on account of necessary repairs to cars.	Occasionally.	No.
One class only.	One class only.	One class only.	One class only.
No such conditions.	No.	No.	No.
No.	Difficulty on account of gas-mech. cars not being powerful enough to haul trailers.	No.	No.
No.	No.	No.	No.
No.	No.	No.	No.
No.	Not at present.	No.	No.
...	...	...	...
...	...	...	...
To economise on operation costs.	To economise on operation costs.	To economise on services which had to be maintained but did not pay. Type of car tends to baggage motor, passenger trailer.	...
No.	No.	No.	...
No.	No.	No.	No.
Uncertain.	Increased power to permit hauling additional trailers.	Larger cars permitting trains of 3 or 4 cars to be run.	Rail motors will be used only where economical.

Name of railway 1	**Missouri-Pacific.** 8	**Missouri-Kansas and Texas.** [illegible]
1. *What observations have you to make on the results obtained in current service from the point of view of power, and, above all, of flexibility in use, with regard to service requirements ?*	...	The two cars are suitable for present runs, but mechanical car is too light for other services.
2. *Have you frequently been obliged to replace rail motor cars (R.M.) by locomotives on occasion of large rush of passengers, either of periodic nature, or during certain seasons, or accidently ?*	No.	Occasionally for special events or repairs.
3. *Have you found it advantageous to reduce the classes to one only, even for the trailers ?*	Only class only.	One class only.
4. *Has the number of runs of rail motor cars interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for principal trains on lines carrying heavy fast passenger and freight train traffic ?*	No.	No.
5. *Have you experienced difficulties in motor upkeep, in view of special construction generally less robust than that of locomotives ?*	No.	Yes for gas-mechanic car. No for gas-electric.
If it is necessary to stable and overhaul rail motor cars in steam locomotives sheds, and in view of the connection of interior of car with mechanical portion, have you experienced trouble due to the deterioration of cars, and the difficulty of keeping them in a good state of cleanliness ?	No.	No.
Have you had trouble due to space so taken up in the sheds ?	No.	No.
6. *Have you in construction other rail motor cars ?*	...	No.
If so, of what type ?	...	...
Are you thinking of extending their use ?	Yes.	Under consideration.
7. *What reasons led to adoption of rail motor car operation, and of particular types of car ?*	...	To economise on operation costs.
8. *As the result of experience, have you altered your views on the question ?*	...	Only gas-electric cars would be considered.
9. *Are you proposing to alter your organisation, or system of operation ?*	No.	No.
If so, in what respect ?		
10. *What is the likely trend of development with regard to rail motors on your railway ?*	...	Probably further gas-electric cars will be obtained.

Minneapolis, St. Paul and Sault Ste. Marie. 10	New York, New Haven and Hartford. 11	Northern Pacific. 12	Reading Company. 13
Load limited to one trailer.	Satisfactory in all respect.	Results obtained have been very satisfactory	More satisfactory than steam.
Yes.	Yes.	Occasionally on holidays and other special occasions.	No.
One class only.	One class only.	Only one class.	One class only.
No.	No.	No.	No.
No.	No. Serviceability superior to steam.	No unreasonable difficulty in any phase referred to.	No.
No.	No.	...	No.
No.	No.	...	No.
No.	No.	None under construction. Will consider extending when business conditions warrant.	No.
...	...		...
...	Under consideration.		...
For test.	To economise on operation costs. Desire for more power led to use of gas-electric.	To provide service at lower cost than it could be done with steam.	To economise on operation costs. Service tests determined types, etc.
No.	No.	No.	No.
No.	No.	No.	No.
..	Likely trend towards train operation.	Possibly heavier units capable of hauling two or more trailers.	No change contemplated.

Name of railway 1	**Southern Pacific.** 14	**Canadian National.** 15
1. *What observations have you to make on the results obtained in current service from the point of view of power, and, above all, of flexibility in use, with regard to service requirements?*	...	From observation most suitable unit is Diesel-elec. 300 H. P. to 400 H. P., capable of hauling one or two trailers.
2. *Have you frequently been obliged to replace rail motor cars by locomotives on occasion of large rush of passengers, either of periodic nature, or during certain seasons, or accidentally?*	...	Yes, 10 % to 15 % of time.
3. *Have you found it advantageous to reduce the classes to one only, even for the trailers?*	...	One class only.
4. *Has the number of runs of rail motor cars interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for principal trains on lines carrying heavy fast passenger and freight train traffic?*	...	No.
5. *Have you experienced difficulties in motor upkeep, in view of special construction generally less robust than that of locomotives?*	...	No.
If it is necessary to stable and overhaul rail motor cars in steam locomotive sheds, and in view of the connection of interior of car with mechanical portion, have you experienced trouble due to the deterioration of cars, and the difficulty of keeping them in a good state of cleanliness?	...	No.
Have you had trouble due to space so taken up in the sheds?	...	No.
6. *Have you in construction other rail motor cars?*	...	Not with present economic conditions.
If so, of what type?	...	...
Are you thinking of extending their use?	...	Yes.
7. *What reasons led to adoption of rail motor car operation, and of particular types of car?*	...	To economise on operating costs. Diesel unit final choice due to cheap fuel, high thermal eff., absence of fire hazard and dependability.
8. *As the result of experience, have you altered your views on the question?*	...	No.
9. *Are you proposing to alter your organisation, or system of operation?* *If so, in what respect?*	...	No.
10. *What is the likely trend of development with regard to rail motors on your railway?*	...	That rail motors will be power units only—will not have accom. for passengers.

Chosen Government. 16	Japanese Government. 17	Federated Malay States. 18	East Indian. 19
Usage limited on account of limited power.	...	Satisfactory.	...
Not frequent at present.	...	No.	Only for breakdown or overhaul.
Yes.	...	No. It is essential to cater for 2 classes.	No.
No.	...	No such conditions.	No such conditions.
With petrol cars difficulty was experienced in water circulating system in Winter.	...	No.	No, but shopping is more frequent than with locomotive.
No.	...	No.	No.
No.	...	No.	No.
No.	...	Five articulated steam units on order.	No.
...	...	...	...
...	...	...	Not at present.
To economise on operating costs and build up traffic.	...	To economise on operating costs.	To economise on operating costs and to counter road competition.
No.	...	No.	Usefulness is limited to certain services.
No.	...	Not as yet.	No.
Further development probable.	...	Extension of use of rail motors.	None.

Name of railway 1	**Nigerian.** 20	**Sudan Government.** 21
1. *What observations have you to make on the results obtained in current service from the point of view of power, and, above all, of flexibility in use, with regard to service requirements ?*	Satisfactory.	Too early to express opinion.
2. *Have you frequently been obliged to replace rail motor cars by locomotives on occasion of large rush of passengers, either of periodic nature, or during certain seasons, or accidentally ?*	No.	No.
3. *Have you found it advantageous to reduce the classes to one only, even for the trailers ?*	No.	No. Racial and social conditions forbid.
4. *Has the number of runs of rail motor cars interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for principal trains on lines carrying heavy fast passenger and freight train traffic ?*	No such conditions.	No.
5. *Have you experienced difficulties in motor upkeep, in view of special construction generally less robust than that of locomotives ?*	No.	No.
If it is necessary to stable and overhaul rail motor cars in steam locomotive sheds, and in view of the connection of interior of car with mechanical portion, have you experienced trouble due to the deterioration of cars, and the difficulty of keeping them in a good state of cleanliness ?	No.	No.
Have you had trouble due to space so taken up in the sheds ?	No.	No.
6. *Have you in construction other rail motor cars ?*	No.	Service still experimental.
If so, of what type ?	...	...
Are you thinking of extending their use ?	...	...
7. *What reasons led to adoption of rail motor car operation, and of particular types of car ?*	Experiment.	Road competition, operating economy. To cope with intensive passenger traffic in cotton producing area. Experimental.
8. *As the result of experience, have you altered your views on the question ?*	No.	Insufficient experience.
9. *Are you proposing to alter your organisation, or system of operation ?* *If so, in what respect ?*	No.	No.
10. *What is the likely trend of development with regard to rail motors on your railway ?*	Improbable that any more will be obtained.	Service still experimental.

South African. 22	New Zealand Government. 23	West Australian Governement. 24	Tasmanian. 25
Still experimental.	Both underpowered and have limited sphere of application. Steam car is of old design. Battery car high in capital costs.	Limited experience, but believe that extension of use will be advantageous.	...
Yes.	Yes for special events.	No.	...
Racial conditions render it difficult to maintain one class.	One class only.	One class only on rail motors.	...
No.	No such conditions.	No.	...
Yes.	Yes.	Small numbers render it difficult to express opinion.	...
No.	No.	No.	...
No.	No.	No.	...
Yes. Six.	No.	Not with present-economic conditions.	...
Same type.	...	...	...
No.	No.	Yes.	...
Originally to reduce costs. Now idea is to give better service than mixed trains.	To counter road competition.	To economise in operating costs.	...
No, except that more powerful car would be of advantage.	Geographical conditions give road the advantage.	No.	...
No.	...	No.	...
Possibly more powerful car to haul trailers. Economics need study.	Further development unlikely.	With return of normal economic conditions extension would be advocated.	...

Name of railway 1	**New South Wales Government.** 26	**New York Central.** 27
1. *What observations have you to make on the results obtained in current service from the point of view of power, and, above all, of flexibility in use, with regard to service requirements ?*	Underpowered.	Limited to a specific service and therefore somewhat inflexible.
2. *Have you frequently been obliged to replace rail motor cars by locomotives on occasion of large rush of passengers, either of periodic nature, or during certain seasons, or accidentally ?*	Yes. On special occasions in country and daily at peak periods in suburbs.	Frequently for short periods on account of heavy traffic.
3. *Have you found it advantageous to reduce the classes to one only, even for the trailers ?*	No.	Yes.
4. *Has the number of runs of rail motor cars interpolated between pre-existing trains given rise to congestion, difficulties with station service, delays for principal trains on lines carrying heavy fast passenger and freight train traffic ?*	No interpolated services—traffic conditions not altered.	No such conditions.
5. *Have you experienced difficulties in motor upkeep, in view of special construction generally less robust than that of locomotives ?*	No.	No. Close inspection and proper maintenance is essential.
If it is necessary to stable and overhaul rail motor cars in steam locomotives sheds, and in view of the connection of interior of car with mechanical portion, have you experienced trouble due to the deterioration of cars, and the difficulty of keeping them in a good state of cleanliness ?	At one depot where steam locos. were adjacent difficulty was experienced in keeping rail motor clean.	No.
Have you had trouble due to space so taken up in the sheds ?	No.	No, although a spare stall must be kept alongside motor.
6. *Have you in construction other rail motor cars ?*	Not at present, but under consideration.	No.
If so, of what type ?	...	...
Are you thinking of extending their use ?	...	Not at present.
7. *What reasons led to adoption of rail motor car operation, and of particular types of car ?*	Provision of economical and speedy transport for small loading.	Economic reasons.
8. *As the result of experience, have you altered your views on the question ?*	No.	No.
9. *Are you proposing to alter your organisation, or system of operation ?*	No.	No.
If so, in what respect ?		
10. *What is the likely trend of development with regard to rail motors on your railway ?*	Increase in power and capacity and improved comfort.	Use of similar cars on services where a reasonable return on investment is assured.